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VOF
GREEN

THE

CHEMISTRY OF THE ARTS;

BEING

A PRACTICAL DISPLAY

OF THE

ARTS AND MANUFACTURES

WHICH DEPEND

ON CHEMICAL PRINCIPLES.

With Numerous Engravings.

ON THE BASIS OF

GRAY'S OPERATIVE CHEMIST,

ADAPTED TO THE UNITED STATES;

WITH

TREATISES ON CALICO PRINTING, BLEACHING, AND OTHER LARGE ADDITIONS.

BY ARTHUR L. PORTER,

LATE PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF VERMONT.

VOL. I.

Philadelphia:

CAREY & LEA.

1830.

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EASTERN DISTRICT OF PENNSYLVANIA, To wit:

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CAREY & LEA,

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"The Chemistry of the Arts; being a Practical Display of the Arts and Manufactures which depend on Chemical Principles. With numerous Engravings. On the Basis of Gray's Operative Chemist, adapted to the United States; with Treatises on Calico Printing, Bleaching, and other large Additions. By Arthur L. Porter, late Professor of Chemistry in the University of Vermont."

In conformity to the Act of the Congress of the United States, entitled, "An Act for the Encouragement of Learning, by securing the Copies of Maps, Charts, and Books, to the Authors and Proprietors of such Copies, during the times therein mentioned"—And also to the Act, entitled, "An Act supplementary to an Act, entitled, 'An Act for the Encouragement of Learning, by securing the Copies of Maps, Charts, and Books, to the Authors and Proprietors of such Copies, during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

D. CALDWELL,

Clerk of the Eastern District of Pennsylvania.

TO THE BINDER.

This work, when bound in 2 vols., should be divided at page 398.

PREFACE.

The want of a book peculiarly devoted to the general practice of the Chemical Arts and Manufactures has been long felt. The practical chemists have been left to find out what they wanted amidst a heap of extraneous matter in Dictionaries, Encyclopædias, or in systems in which the theory of chemistry was the principal object; and all of these sources being written in the new language of the day in which they were published, necessitated the mere practical man to learn the language and theory of that day, to his great loss of time, so that he frequently threw away the book in disgust, rather than encounter this difficulty.

The English library is peculiarly deficient in works upon the chemical arts. In the reign of Charles II. a few books on these subjects made their appearance, as Stalker on Japanning, Purfoot on Dyeing, a small work, but which contains the most accurate information, and which Dr. Bancroft allows not to be surpassed by any subsequent work on the subject. The processes of a few chemical arts, as refining, and the making of copperas and alum, were given in the Philosophical Transactions, and Mr. Ray, at the end of his English Proverbs, has given an account of the processes used at the mineral works of his time. In the perusal of these books it is astonishing to find how few and slight are the differences between the old prac-

tice and that of the present day. Larger capitals are employed, and more elegant forms given to the articles produced, but the real substantial parts of the processes used still remain nearly as they were. For this improvement in the forms, we are indebted to the Society for the Encouragement of Arts, Manufactures, and Commerce.

At present, the publication of the letters patent taken out by various projectors, in the Repertory of Arts, and other periodical publications, furnish the principal sources of information respecting these arts. And the incidental information they give of the actual practice, is for the most part far more valuable than the new schemes that they propose for its amendment.

To collect this information, and to join with it what could be found in the two great French Encyclopædias, the Dictionnaire Technologique, now in course of publication, and in several foreign periodical works, in which the chemical arts form a part of the plan, has been the object of the author. How far he has succeeded, must be left to the reader to judge. It is, however, necessary to state, that the author has laboured nearly the whole time, and especially towards the end, under the pressure of the severest illness, so that his life was, and is still, despaired of, and therefore he solicits a favourable view of any mistakes into which he may have fallen, or any omissions of which he may be guilty.

It has not been thought advisable to adopt all the alterations in nomenclature to which the progress of chemical science is continually giving rise, but rather

to avoid, as much as possible, substituting names newly given to substances, for those by which they have hitherto been distinguished. It is particularly requested that it may be distinctly understood that no opinion whatever is offered by the author upon the soundness of the numerous alterations which are daily taking place in the different schools, but that the popular nomenclature has been adhered to simply because it is popular, and the Lavoisierian nomenclature in other cases, because it is very doubtful whether the advantage of what may possibly be a more perfect nomenclature, is not surpassed by the disadvantage of perplexing the memory of indifferent and uninformed persons with changes, the propriety of which is only felt by the accomplished philosophical Chemist.

There is another reason that real practical Chemists should avoid habituating themselves to continual changes of names, lest they should have occasion to take out letters patent for any invention of their own. For it being an essential point that the invention should be so plainly described that any person may, at the expiration of the term, produce the like, the Court of King's Bench determined, in the case of Savory against Price and Son, that the composition of the Seidlitz powders not being described under the popular names, and in the plainest manner, the letters patent were themselves void. It being necessary that patentees should use the popular language, and denominate the several substances by the names under which they are known in the Book of Rates, and the Statutes of the Realm; and if not to be found there, by the most usual names under which they are sold by the dealers in them, to workmen and others, and that if articles are

PREFACE,

BY THE AMERICAN EDITOR.

At the commencement of the present year, the writer proposed to the publishers of this work to furnish for the press a small volume of essays on the bleaching of cotton and linen, calico printing, the manufacture of oil of vitriol, and bleaching powder, and several other of the more important branches of the Chemical Arts. He then learned that they were contemplating the republication of Gray's Operative Chemist, the general design of which was so similar to the more limited treatise proposed by him, the subjects so nearly connected, and in some instances identically the same, that the plan of incorporating the two works was suggested by the publishers, and, on mature consideration, adopted. Such was the origin of the present volume. The *Operative Chemist* was published in London in 1828, and is the first systematic treatise on the application of chemistry to the arts generally since the publication of *Aikin's Chemical Dictionary*, now about thirty years. The great discoveries in the science of chemistry, and consequent improvements in the Chemical Arts and Manufactures, within that period rendered a new work on the latter peculiarly desirable. The *Operative Chemist* was designed to exhibit a practical view of the numerous arts and manufactures dependent on chemical principles. It was

drawn up by one of the ablest operative chemists of Great Britain, who was practically conversant with most of the subjects treated of in his work, who enjoyed the facilities afforded by the Metropolis, of an extensive intercourse with the first scientific and practical men of the age, and of collecting and collating the numerous articles of practical intelligence scattered through the periodical journals of the present century. It remains to show in what respect the present volume differs from the work of Mr. Gray. With the exception of some few arts and processes not practised, and from local causes not likely to be practised, in the United States, the entire *practical* matter of the "*Operative Chemist*" has been preserved. Much, however, of the theoretical parts has been expunged, and its place supplied by other matter. The articles on Electricity and Galvanism, for instance, have been wholly omitted, as having not even the shadow of a claim to a place in a purely practical work on the arts. The beautiful discoveries, and apparatus, of Professor Hare should have a conspicuous place in every work which professes to treat of the general doctrines of chemistry; but they have not the remotest application to the practical processes of the arts. Nearly the same thing may be said of the articles on the compound blow-pipe, on burning-glasses and lenses, on light and many others, having reference merely to the principles of the science which, however interesting to the student of chemistry, are of little utility in the workshop, and may be found more fully treated of in almost every elementary work on the science generally;—they are, therefore, likewise omitted. The name of Mr. Gray's work has been exchanged for one, which accords better with its real objects and design, and particularly

with the contributions by the writer, which are exclusively of a practical nature, and for the most part contain the results of actual observation on the most extensive scale of manufacture. The additions by the writer are designated "*Operative Chemist*," by brackets. His steady purpose, both in abridging the original work, and in the contribution of new matter, has been to increase the practical value of the volume to the American manufacturer and operative chemist. How far he may have succeeded in that desirable object, a discerning public will judge.

A. L. PORTER.

Dover, N. H., September 8th, 1830.

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CHEMISTRY

APPLIED TO THE ARTS.

THE philosophical chemists have gradually reduced the quantity of material upon which they operate to such minuteness, that they are enabled, in most cases, to do without furnaces, or any laboratory, but an ordinary library table: real practical chemists, however, find it necessary, even for the purpose of experiment only, to operate upon a larger scale; and to devote a room or building for the performance of their processes, that is known by the technical appellation of a laboratory.

The larger laboratories, or workshops, which are used only in particular branches of business, and the necessary apparatus attached to them, will be considered under the several substances which are prepared in them. Besides the workshop, every operative chemist ought to devote some part of his premises as a small general elaboratory, fitted up with such furnaces and other apparatus as may enable him to make any experiment seemingly applicable to the improvement of his manufacturing processes without loss of time, and immediately upon its conception. For want of this immediate appeal to experiment, many excellent thoughts have been lost to the manufacturing chemist.

It may be thought unnecessary for the experimental laboratory, here recommended to the operative chemist, to contain any other than his ordinary apparatus upon a smaller scale, on the ground that the metallurgist can have no occasion for the copper still boilers and copper pans of the pharmaceutical operator; nor the latter have any occasion for the wind and blast furnaces of the metallurgist. But although this is in some measure true, yet it is certain that the experimental laboratory ought to be furnished on the most general principles.

In many books of chemistry there are given very minute directions respecting the building and furnishing an experiment allaboratory, founded evidently on the idea that the chemist has sufficient space and command of money to do as he pleases in this respect. On these minute directions Dr. Ber-

kenhout pleasantly observes, that surely a chemist does not need to be informed that, in furnishing his elaboratory, he must not forget a nail upon which he may hang his hat, or a towel to wipe his hands.

As the object of the operative chemist is to apply to use the alterations that take place in bodies by the action of heat and cold upon them, and the combinations or separations that occur in their admixture with one another; therefore heat, whether it be a peculiar species of matter, or a peculiar kind of motion excited amongst the particles of bodies, is of the greatest importance in the practice of this art, and the modes of administering must be first considered. Of course, the furnaces for exposing the bodies, operated upon to the action of heat, are the principal part of the apparatus required by an operative chemist; and these are constructed differently, according to the nature of the fuel used in the country.

Where charcoal can be used without much increase of expense, it should always be preferred, on account of its being so much more manageable than any other species of fuel; and to attain this advantage it will frequently be preferable to make the experiments upon a small quantity of materials rather than forego its use; but in most parts of this country pitcoal and coke, from their cheapness, are the ordinary fuel burned in furnaces of all kinds.

Dr. Thomas Thomson, of Glasgow, has made a minute analysis of the different kinds of coals used in that manufacturing town; but these analyses are of little use to practical men. They serve to display the abilities of the operator in analysis, to ascertain the place of the substance in the theoretical system that is in fashion at the time; but for practical purposes, the relative heating powers of the several species of fuel are the thing that is required, in order that by combining this with their respective prices, their relative value may be discovered.

THE RELATIVE VALUE OF FUEL.

Whatever kind of fuel it may be considered best to employ, it is extremely desirable that it should be as dry as possible, otherwise a great part of the heat it contains will be lost in converting the water in the fuel into vapour, which of course escapes up the chimney without producing any useful effect.

Fuel is often unnecessarily exposed to the weather, or put in wet places; and the injurious effect of introducing damp into a close fire-place is never considered.

Pit-Coals.

There is considerable difference between the pit-coals; and it has perhaps been too little attended to by those who are the chief consumers of this expensive article. The subject has not even been studied with much attention, except so far as relates to the production of gas; and the facts that have been established by these researches are not very useful in other applications of fuel.

Caking coal, also called binding coal, crozzling coal, is obtained in great abundance from the extensive coal-fields in Northumberland and Durham; and is that which is sold in the London market as Newcastle coal.

When heated, this coal breaks asunder into small pieces; and the heat being raised to a certain degree, the pieces cohere, and form a solid mass, from which property it is called caking-coal. It lights easily, and burns with a lively yellow flame. It requires to be frequently stirred or broken up, particularly when it cakes very hard; but different varieties differ considerably in this property. Of the Newcastle coals, the best Wall's End make a brilliant and pleasing fire, burn away quickly, and do not cake hard, hence it is preferred for heating rooms; but the Tanfield Moor burn slowly, cake very hard, and afford a strong and long-continued heat, and is used in furnaces and forges. The other varieties are of an intermediate character.

Caking coal gives out a great quantity of heat, and, with attention, burns a long time; consequently, where it can be procured at a reasonable price, it is commonly preferred.

From the trials of Mr. Watt, it appears that a bushel of Newcastle coals, which weigh, on an average, eighty-four pounds, will convert from eight to twelve cubic feet of water into steam, from the mean temperature of the atmosphere; and that a bushel of Swansea coal will produce an equal effect.

Dr. Black states to the effect, that 7 pounds .91 of the best Newcastle-coal will convert one cubic foot of water into steam, capable of supporting the mean pressure of the atmosphere.

In some experiments tried by Messrs. Parkes, it appears, that by their improved method of constructing boilers, an effect was obtained, equivalent to converting one cubic foot of water into steam from the mean temperature, with 7 pounds .45 of coal, in the case where the greatest effect was produced; but at a mean, 8 pounds .15 of coal were necessary to produce the same effect; which is only one quarter of a pound less than the mean of Mr. Watt. From a mean of several experiments, Smeaton makes it require 11 pounds .4 of coal to produce the same effect; but the kind of coal is not described.

Mr. Tredgold found that after the brick-work, &c. of the boiler of a steam-engine was warmed, a little less than one pound of Wall's-End coals would make a cubic foot of water boil, from the mean temperature of fifty-two degrees. To produce the same effect with inferior coals, a stronger draught, and more time and attention, was necessary.

Splint-Coal,

Or hard coal, called slaty cannel coal by Kirwan, is esteemed equally valuable, for many purposes, as the Newcastle caking coal. It is obtained near Glasgow, in Ayrshire, Scotland, and in several of the English and Welsh coal-fields.

A greater heat is necessary to make it kindle than is required for caking-coal; and consequently it is not so well adapted for a small fire; but a large body of splint coal makes a strong and lasting fire. It does not produce so much flame, nor so much smoke, as caking coal, and does not agglutinate or bind together.

The splint coal of Scotland was considered by Smeaton to be equal to Newcastle coal for steam-engines.

Cherry-Coal,

Or soft coal, constitutes, says Dr. Thomson, the greater part of the upper seams of coal in the Glasgow coal-fields; and it is also abundant in Fifeshire. He considers the Staffordshire coal to be of the same species; and the Edinburgh as intermediate between it and splint-coal.

It readily catches fire, and burns with a clear yellow flame, giving out much heat; and the flame continues till nearly the whole of the coal be consumed. It burns away more rapidly than either caking or splint coal, and leaves a white ash. For most purposes it is less economical. It is easily distinguished from caking coal, by its not melting or becoming soft when heated. It makes a more agreeable fire, and does not require to be stirred. It requires care and management in an open grate, even to burn the small fragments which are made in breaking up the pieces to a fit size for the fire. Hence the small coals are often mixed with clay and made into balls. When these balls are dry, they make an excellent addition to the fuel for an open fire, producing a very durable heat.

Mr. Watt states that one hundred weight of good Wednesbury coal will produce the same effect as one bushel of Newcastle coal.

Wood.

In some places wood is used for fuel; its effect in producing heat is found to depend considerably on its state of dryness.

Several experiments, made by Count Rumford, show the effect of dry wood to be much greater than that of unseasoned. Unseasoned wood contains about one third of its weight of water. The kind of wood is also a cause of some difference; from the experiments of Count Rumford, lime-tree wood gives out most heat in burning.

With his improved boilers Count Rumford made 20 pounds .10 of ice-cold water boil with one pound of dry pine wood. The same weight of pine wood unseasoned, would produce less effect by one-seventh. Beech wood afforded much less heat than pine; for one pound of dry beech made 14 pounds .33 of ice-cold water boil. A cubic foot of dry beech weighs about forty-four pounds.

According to Fossombroni, wood produces heat enough in its combustion to evaporate twice its weight of water, or to prepare two-thirds of its weight of salt. Count Rumford's trials make the effect of wood about one-third more, which may fairly be attributed to his superior skill.

Peat,

Considered only as a fuel, may be divided into two kinds. The first is compact and heavy, of a brownish black colour, and with scarcely any vestiges of its vegetable origin remaining. This is the best kind. When it is once lighted it preserves fire along time.

The second kind is light and spongy, of a brown colour, and seems to be a mass of dead plants and roots which have undergone very little change; it inflames readily, and is quickly consumed.

Peat gives out an odour, while it is burning, which is disagreeable to those who are not accustomed to it. It affords a mild and gentle heat; but is not a good kind of fuel for supplying furnaces for boilers; it is much better adapted for flues. It is of various qualities; some burn quickly with a bright flame; others burn slowly, and, according to Clément and Desormes, afford one-fifth of the heat that would be given out by an equal weight of charcoal. This nearly coincides with the ratio given by Blavier and Miché.

The weight of a cubic foot varies from forty-four to seventy pounds; and the dense varieties afford about forty per cent. of charcoal; the other varieties nearly in proportion to their density.

Charcoal.

Mr. Dalton, by heating water, obtained a result equivalent to melting forty pounds of ice with one pound of charcoal.

But Dr. Crawford's experiments give sixty-nine pounds of ice melted by one pound of charcoal. Lavoisier's give ninety-five pounds and a half; Clément and Desormes ninety-five pounds, and Hassenfratz's trials, on various kinds, give a mean of ninety-two pounds of ice melted by one pound of charcoal; his highest result being ninety-six pounds, and lowest one seventy-four pounds. Mr. Tredgold considers forty-seven pounds of ice melted by one pound of charcoal as the real average effect of that fuel. A cubic foot of charcoal weighs about fifteen pounds.

Coke.

Lavoisier makes the quantity of coal to be that of coke as 605 is to 552 when the same effect is produced; and in addition to this increased power of giving out heat, it must also be considered that coke gives out no smoke in burning: whence it should always be used in furnaces seated in towns, in order to prevent any annoyance to the neighbours.

The present prevalent use of gas, for lighting towns and even houses, has brought a considerable quantity of *gas coke* into the market, which does well enough for heating rooms, but is far inferior to the stifled coke in its heating power, so that smiths and iron-founders invariably use the latter kind, and when a great heat is required, the chemist should follow their example.

Coke has been tried against wood in Paris for warming the Opera-House. Fifty-eight pounds of coke, costing there about 1*s.* 3*d.*, produced the same effect as 160 pounds of wood, costing there about 2*s.* 6*d.*

Charred Peat.

According to Messrs. Blavier and Miché it requires 1666 pounds of charred peat to produce the same effect as 740 pounds of common charcoal.

The charred peat, made by stifling, is superior, in its power of producing heat, to that made by distillation. Unfortunately the stifled charred peat is a kind of pyrophorus, which takes fire if it becomes accidentally wetted, or even in moist weather. In consequence of this property several accidents have happened by the rain finding its way into places where it is kept; it is on this account forbidden, by the laws of some countries, to be kept in towns.

Therefore the Dutch, who burn this fuel not only in their houses, but even in pans under their feet while they are at church in winter, are in the habit of charring it at home as it is wanted. It is first burnt in the kitchen, and when they find it is red hot quite through, they then take it off the fire, put it

in a close earthen or copper pot, and cover it down with a wet woollen or linen cloth, and by the air being excluded the fire is soon extinguished, and when it is cold it will resemble charcoal, except being covered with white ashes, and will, if properly charred, burn with scarce any smoke, and very little of the suffocating quality which charcoal has. This it is that makes the charred peat so proper for green houses, for charcoal burnt in them is very prejudicial to the plants, and often fatal to the person who attends them.

[The intelligent author has here certainly fallen into a popular error in regard to the true cause of the suffocating quality of burning charcoal. The product of the combustion of charcoal must be essentially the same as from charred peat: the combustible part of both is little else than pure carbon, and the products of their combustion are of course pure carbonic acid. The popular notion is, that the unpleasant odour exhaled from burning charcoal, which has for some time been exposed to a damp atmosphere, and particularly when first ignited, is the suffocating principle: hence the common impression that ignited charcoal taken from a common fire may be burned with impunity in an unventilated room, and that charred peat, which does not exhale the peculiar odour of charcoal, is a safer and less objectionable fuel under the same circumstances. Many lives are annually sacrificed from this erroneous notion. The only true ground of preference of charred peat for burning in green houses is the slow and gradual manner in which it consumes. Charcoal, in this respect, is much less manageable. It is the sudden and unequal heats from charcoal, rather than any essential difference in the product, that renders its use so objectionable.]

The usual method of burning this peat in Holland, especially by the poor, is in cast iron-kettles, and for boiling any thing over it this way saves half the fire it would otherwise take if burnt on a hearth, or in a grate, by the side of the pot reflecting the heat.

[The small Philadelphia furnaces, fabricated from the South Amboy clay of New Jersey, now in general use in our Atlantic cities, are admirably calculated to secure an economical expenditure of heat in the combustion of charcoal for culinary purposes, and for a similar reason. But they ought never to be used in an unventilated room.]

Adjoining to many of the capital towns in Holland there are a great number of small gardens with little summer houses, most of which are built with wood. Near Rotterdam there are nearly a thousand of these gardens, and almost all of them have some orange trees in them. In the winter they are preserved from the intense frosts, which generally last there for nearly

three months, by means of this charred peat, the natural firing of that country, which is burnt in an earthen pan, or cast iron pot, in these little summer houses.

A collected view of the data from these experiments and comparisons is given by Mr. Tredgold. It is as follows:

Kind of Fuel.	Fraction of a pound that will heat one cubic foot of water one degree of Fahrenheit's scale.	pounds of fuel that will convert one cubic foot of water into steam.
Newcastle, or caking Coal	0·0075	8.40
Splint Coal	0·0075	8·40
Staffordshire cherry Coal	0·0100	11·20
Wood, dry pine	0·0172	19·25
—— dry beech	0·0242	27·00
—— dry oak	0·0265	30·00
Peat, of good quality	0·0475	53.60
Charcoal	0·0095	10·60
Coke	0·0069	7·70
Charred Peat	0·0205	23·00

It will appear, as Mr. Tredgold justly observes in his very excellent "Principles of Warming and Ventilating Public Buildings," that the utmost effect we can hope to gain in applying fuel must be less than double the measure of effect here given; and even to attain that effect all the caution of conducting a philosophical experiment must be continually employed, which will be found impracticable on a large scale, and altogether incompatible with the simple apparatus and small share of attention which can be devoted to this end in real business, although there are not wanting persons who promise four, six, and even ten times these effects.

Improvement of Fuel by Mixture.

It is surprising that so few attempts should be made to improve the fires which are made in the open chimneys of elegant apartments by preparing the fuel; for, as Count Rumford observes, nothing surely was ever more dirty, inelegant, and disgusting than a common coal fire.

Fire balls, of the size of goose eggs, composed of coal and charcoal in powder, mixed up with a due proportion of wet clay, and well dried, would make a much more cleanly, and, in all respects, a pleasanter fire than can be made with crude coals; and it is believed would not be more expensive fuel. In Flanders, and in several parts of Germany, and particularly in the duchies of Juliers and Bergens, where coals are used as fuel, the coals are always prepared before they are used, by pounding them to a powder, and mixing them up with an

equal weight of clay, and a sufficient quantity of water to form the whole into a mass, which is kneaded together and formed into cakes; which cakes are afterwards well dried, and kept in a dry place for use. And it has been found, by long experience, that the expense attending this preparation is amply repaid by the improvement of the fuel. The coals thus mixed with clay not only burn longer, but give much more heat than when they are burnt in their crude state.

It will doubtless appear extraordinary to those who have not considered the subject with some attention, that the quantity of heat produced in the combustion of any given quantity of coal should be increased by mixing the coals with clay, which is certainly an incombustible body; but the fact is certain.

In composing fire balls, it is probable that a certain proportion of chaff, of straw cut very fine, or even of saw-dust, might be employed with great advantage. It is wished that those who have leisure would turn their thoughts to this subject; for it is conceived that very important improvements would result from a thorough investigation of it.

For the purpose of lighting a fire speedily, *kindling balls*, composed of equal parts of coal, charcoal, and clay, the two former reduced to a fine powder, well mixed, and kneaded together with the clay moistened with water, and then formed into balls of the size of hen's eggs, and thoroughly dried, might be used with great advantage instead of wood.

These kindling balls may be made so inflammable as to take fire in an instant, and with the smallest spark, by dipping them in a solution of nitre, and then drying them again; and they would neither be expensive nor liable to spoil by long keeping. Perhaps a quantity of pure charcoal, reduced to very fine powder, and mixed with the solution of nitre in which they are dipped, would render them still more inflammable.

[The foregoing meagre account of the relative value of several varieties of fuel, as determined by the heat produced in combustion, comprises about all the information which the labours of Crawford, Lavoisier, Rumford, Watt, Dalton, Clement, Desormes, and other philosophers, have shed upon the subject previous to the publication of Mr. Bull of Philadelphia, entitled "Experiments to Determine the Comparative Value of the Principal Varieties of Fuel used in the United States and in Europe," read before the American Philosophical Society of Philadelphia, in April, 1826. This is by far the most extended, systematic, and successful, effort yet made in this interesting field of experimental inquiry. I am indebted to the politeness of Mr. Bull for permission to transcribe the tabular results of his experiments, and such other portions of his interesting paper as more immediately comports with the practical character and design of this work; but would earnestly recom-

mend the perusal of the whole paper to every scientific manufacturer, or artisan, whose processes involve any considerable consumption of fuel, as well as to enlightened readers of every class; for no subject is more generally interesting in our cold climate than the most economical means of producing artificial heat.

The general principle on which Mr. Bull's experiments were conducted, for determining the comparative heat evolved in the combustion of the different varieties of fuel operated on, was to burn them in a close room, and note the time that the combustion of a given weight of each would sustain the air of the room at a temperature of 10° above the surrounding medium. To obviate the influence which the ordinary atmospheric changes of temperature and the winds would produce on the results, by furnishing a surrounding "refriguating medium of inconstant power," the room in which the experiments were performed was surrounded by double walls, and the intermediate spacesustained by artificial heat during the experiments, at a uniform temperature, and somewhat higher than the greatest natural temperature of the external atmosphere. The actual temperature of the inner and the outer rooms, during the experiment, was determined by common mercurial thermometers suspended in each, and the difference of temperature by Leslie's differential thermometer, the horizontal part of which traversed the inner wall, or partition, leaving a bulb and upright stem on each side. The combustion was effected in a small upright cylindrical stove, furnished with forty-two feet of sheet iron pipe of two inches diameter, having in it several convolutions before it left the room. So completely was the heat generated in the process of combustion dissipated by the pipe, and emitted into the room, that a thermometer, the bulb of which was inserted in the pipe just before it entered the chimney, indicated the same temperature as the one which hung in the room. As the conducting power of air, in relation to caloric, is influenced by its hygrometric state, care was taken to preserve it in a uniform condition in this respect. All the varieties of fuel operated on were dried previous to combustion, at a temperature of 250°, Fahrenheit. Their solid contents were determined in the usual method for irregular bodies, by the volume of water, which a given volume by the usual admeasurement displaces, and the specific gravities by the hydrostatic balance. In the latter case, porous substances, which expand by the absorption of water, as the wood, were previously covered with a varnish having exactly the same specific gravity as water; in short, no precaution seems to have been omitted by this laborious and able experimenter, to guard against every source of error, both in the construction of his apparatus, and in the general conduct of his inquiries. The following table exhibits the results of his experiments on sixty-six varieties of fuel.

Common Names of Woods and Coals.	Botanical Names.	Specific Gravities of dry Wood.	A pou Woo
White Ash, . . .	*Fraxinus americana*, .	.772	
Apple Tree, . . .	*Pyrus malus*, . . .	.697	
White Beech, . . .	*Fagus sylvestris*, . .	.724	
Black Birch, . . .	*Betula lenta*, . . .	.697	
White Birch, . . .	*Betula populifolia*, .	.530	
Butter-nut, . . .	*Juglans cathartica*, .	.567	
Red Cedar, . . .	*Juniperus virginiana*,	.565	
American Chesnut, .	*Castanea vesca*, . .	.522	
Wild Cherry, . . .	*Cerasus virginiana*, .	.597	
Dog Wood, ...	*Cornus florida*, . . .	.815	
White Elm, . . .	*Ulmus americana*, . .	.580	
Sour Gum, ...	*Nyssa sylvatica*, . .	.703	
Sweet Gum, . . .	*Liquidumbar styraciflua*,	.634	
Shell-bark Hickory,	*Juglans squamosa*, .	1.000	
Pig-nut Hickory, .	*Juglans porcina*, . .	.949	
Red-heart Hickory,	*Juglans laciniata?* . .	.829	
Witch-Hazel, . .	*Hamamelis virginica*, .	.784	
American Holly, .	*Ilex opaca*, ...	.602	
American Hornbeam,	*Carpinus americana*, .	.720	
Mountain Laurel, .	*Kalmia latifolia*, . .	.663	
Hard Maple, . . .	*Acer saccharinum*, . .	.644	
Soft Maple, . . .	*Acer rubrum*, . . .	.597	
Large Magnolia, .	*Magnolia grandiflora*,	.605	
Chesnut White Oak,	*Quercus prinus palustris*,	.885	
White Oak, . . .	*Quercus alba*, . . .	.855	
Shell-bark White Oak,	*Quercus obtusiloba?* .	.775	
Barren Scrub Oak, .	*Quercus catesbæi*, . .	.747	
Pin Oak, ...	*Quercus palustris*, . .	.747	
Scrub Black Oak, .	*Quercus banisteri*, . .	.728	
Red Oak, ...	*Quercus rubra*, . . .	.728	
Barren Oak, . . .	*Quercus ferruginea*, .	.694	
Rock Chesnut Oak, .	*Quercus prinus monticola*,	.678	
Yellow Oak, . . .	*Quercus prinus acuminata*,	.653	
Spanish Oak, . . .	*Quercus falcata*, . .	.548	
Persimon, ...	*Diospyros virginiana*,	.711	

of from dry y	Specific Gravities of dry Coal.	Pounds of dry Coal in one bushel.	Pounds of Charcoal from one cord of dry Wood.	Bushels of Charcoal from one cord of dry Wood.	Time 10° of Heat were maintained in the room, by the combustion of one pound of each article.	Value of specified quantities of each article, compared with Shell-bark Hickory as the Standard.
					H. M.	Cord.
4	.547	28.78	888	31	6 40	77
	.445	23.41	779	33	6 40	70
2	.518	27.26	635	23	6	65
0	.428	22.52	604	27	6	63
	.364	19.15	450	24	6	48
9	.237	12.47	527	42	6	51
2	.238	12.52	624	50	6 40	56
9	.379	19.94	590	30	6 40	52
0	.411	21.63	579	27	6 10	55
	.550	28.94	765	26	6 10	75
5	.357	18.79	644	34	6 40	58
6	.400	21.05	696	33	6 20	67
9	.413	21.73	558	26	6	57
2	.625	32.89	1172	36	6 40	100
2	.637	33.52	1070	32	6 40	95
0	.509	26.78	848	32	6 30	81
0	.368	19.36	750	39	6 10	72
7	.374	19.68	613	31	6 20	57
	.455	23.94	611	25	6	65
1	.457	24.05	712	30	6 40	66
1	.431	22.68	617	27	6 10	60
:	.370	19.47	551	28	6	54
0	.406	21.36	584	27	6 10	56
5	.481	25.31	900	36	6 30	86
1	.401	21.10	826	39	6 20	81
0	.437	22.99	745	32	6 20	74
8	.392	20.63	774	38	6 30	73
:	.436	22.94	742	32	6 20	71
0	.387	20.36	774	38	6 30	71
5	.400	21.05	630	30	6 20	69
7	.447	23.52	694	29	6 20	66
5	.436	22.94	632	28	6	61
1	.295	15.52	631	41	6 10	60
	.362	19.05	562	30	6 20	52
	.469	24.68	745	30	6 30	69

Common Names of Woods and Coals.	Botanical Names.	Specific Gravities of dry Wood.	Avoir pounds Wood
YELLOW PINE, (SOFT,)	*Pinus mitis,* . . .	.551	24
JERSEY PINE, . . .	*Pinus inops,* . . .	.478	21
PITCH PINE, . . .	*Pinus rigida,* . . .	.426	19
WHITE PINE, . . .	*Pinus strobus,* . . .	.418	18
YELLOW POPLAR, . .	*Lyriodendron tulipifera,*	.563	25
LOMBARDY POPLAR, .	*Populus dilatata,* . .	.397	17
SASSAFRAS, ...	*Laurus sassafras,* . .	.618	27
WILD SERVICE, . .	*Aronia arborea,* . .	.887	39
SYCAMORE, ...	*Acer pseudo-platanus,* .	.535	23
BLACK WALNUT, . .	*Juglans nigra,* . . .	.681	30
SWAMP WHORTLE-BERRY,	*Vaccinium corymbosum,*	.752	33
LEHIGH COAL, . . .	. . . . .	. .	.
LACAWAXEN COAL, .	. . . . .	. .	.
RHODE-ISLAND COAL, .	. . . . .	. .	.
SCHUYLKILL COAL, .	. . . . .	. .	.
SUSQUEHANNA COAL, .	. . . . .	. .	.
SWATARA COAL, . .	. . . . .	. .	.
WORCESTER COAL, .	. . . . .	. .	.
CANNEL COAL, . . .	. . . . .	. .	.
LIVERPOOL COAL, . .	. . . . .	. .	.
NEWCASTLE COAL, .	. . . . .	. .	.
SCOTCH COAL, . . .	. . . . .	. .	.
KARTHAUS COAL, . .	. . . . .	. .	.
RICHMOND COAL, . .	. . . . .	. .	.
STONY CREEK COAL, .	. . . . .	. .	.
HICKORY CHARCOAL, .	. . . . .	. .	.
MAPLE CHARCOAL, .	. . . . .	. .	.
OAK CHARCOAL, . .	. . . . .	. .	.
PINE CHARCOAL, . .	. . . . .	. .	.
COAK, ...	. . . . .	. .	.
COMPOSITION OF TWO PARTS LEHIGH COAL, ONE CHARCOAL, AND ONE CLAY, BY WEIGHT,	. . . . .	. .	.

Product of Charcoal from 100 parts of dry Wood, by weight.	Specific Gravities of dry coal.	Pounds of dry coal in one bushel.	Pounds of Charcoal from one cord of dry Wood.	Bushels of Charcoal from one cord of dry Wood.	Time 10° of Heat were maintained in the room, by the combustion of one pound of each article.	Value of specified quantities of each article, compared with Shell-bark Hickory as the standard.
					H. M.	Cord.
23.75	.333	17.52	585	33	6 30	54
24.88	.385	20.26	532	26	6 40	48
26.76	.298	15.68	510	33	6 40	43
24.35	.293	15.42	455	30	6 40	42
21.81	.383	20.15	549	27	6 10	52
25	.245	12.89	444	34	6 40	40
22.58	.427	22.47	624	28	6 20	59
22.62	.594	31.26	897	29	6 20	84
23.60	.374	19.68	564	29	6 30	52
22.56	.418	22	687	31	6 20	65
23.30	.505	26.57	783	29	6 30	73
						Ton.
. .	1.494	78.61	. .	. .	13 10	99
. .	1.400	73.67	. .	. .	13 10	99
. .	1.438	75.67	. .	. .	9 30	71
. .	1.453	76.46	. .	. .	13 40	103
. .	1.373	72.25	. .	. .	13 10	99
. .	1.459	76.77	. .	. .	11 20	85
. .	2.104	110.71	. .	. .	7 50	59
						100 Bushels.
. .	1.240	65.25	. .	. .	10 30	230
. .	1.331	70.04	. .	. .	9 10	215
. .	1.204	63.35	. .	. .	9 20	198
. .	1.140	59.99	. .	. .	9 30	191
. .	1.263	66.46	. .	. .	9 20	208
. .	1.246	65.56	. .	. .	9 20	205
. .	1.396	73.46	. .	. .	9 50	243
. .	.625	32.89	. .	. .	15	166
. .	.431	22.68	. .	. .	15	114
. .	.401	21.10	. .	. .	15	106
. .	.285	15	. .	. .	15	75
. .	.557	29.31	. .	. .	12 50	126
. .	. .	. .	. .	. .	13 20	

On the first inspection of the foregoing table I was surprised, as I presume others have been, at the general aspect of the 10th column in relation to the wood. The difference in the heat produced by the combustion of equal weights of dry woods is much less than I had apprehended, and such as to induce a momentary suspicion of the general accuracy of the results. The extreme times in which given weights of forty-six varieties of dry woods sustained a temperature, in the inner room, of 10° above the surrounding medium, are only as 9 to 10. If we turn to the 5th column, we observe a remarkable coincidence between the weight of charcoal, which each variety of wood yields, and the heat produced by combustion. This correspondence is noticed by Mr. Bull. It is not exact, but sufficiently so to justify the inference, that the small difference in the actual value of fuel, as determined by the heat emitted on combustion, is mainly attributable to variations in the quantity of carbon they contain. As the results in these two columns were obtained by actual experiment, and by processes entirely dissimilar, the coincidence noticed affords a strong confirmation of the general correctness of both.

The eight first columns of figures, in the above general table, contain the results of actual experiments, for the details of which I must refer the reader to Mr. Bull's work. The last column is obtained by calculation. Mr. Bull found that shell-bark hickory has the greatest specific gravity of all the varieties of wood experimented on, (as indicated in the table;) and, as an equal weight of it was observed to maintain a given temperature in the room as long a time as any other, it follows that a cord of this wood would yield the greatest amount of heat in combustion: assuming, therefore, the specific gravity of shell-bark hickory to be 1.000, and its value as 100, the value of the other woods must be in the compound ratio of their respective specific gravities, and the time which a given weight was found to sustain the required temperature, and is given in decimal expressions of this last number On this subject Mr. Bull observes, "that although shell bark hickory has been taken, for convenience, as the standard to construct the column of comparative values, the economist should take the cheapest article of fuel in the market, as his standard of comparison."

If we assume the average quantity of charcoal yielded by the dry woods to be 20 *per cent.* by weight, and the average time that a pound of dry wood sustained a temperature of 10° above the surrounding medium in Mr. Bull's Experiments, to be six hours (both of which terms are below the truth, but which sustain to each other about the ratio, which we observe between the 5th and 10th columns in his table,) it results that just 50 *per cent.* of the heat emitted in the combustion of dry wood is to

be attributed to the combustion of the carbon which it contains: for one pound of charcoal sustained the temperature of the room, at the required point, just two and a-half times as long as the assumed average time that a pound of wood would do, which yields 20 *per cent.* of charcoal, and .20×2.5=.500.

The following remarks of Mr. Bull are full of interest to the economist of fuel. "From experiments made to ascertain the weight of moisture absorbed by the different woods, which had previously been made perfectly dry, and afterwards exposed in a room in which no fire was made during a period of twelve months, the average absorption by weight, for this period, was found to be 10 *per cent.* in forty-six different woods, and 8 *per cent.* in the driest states of the atmosphere; and an unexpected coincidence was found to exist in the weight absorbed by forty-six pieces of charcoal, made from the same kinds of wood, and similarly exposed, the latter being also 8 *per cent.*

"The quantity of moisture absorbed by the woods individually was not found to diminish with their increase in density; whilst it was found that the green woods in drying uniformly lost less in weight in proportion to their greater density. Hickory wood, taken green, and made absolutely dry, experienced a diminution, in its weight, of 37½ *per cent.*, white oak 41 *per. cent.*, and soft maple 48 *per cent.* A cord of the latter will, therefore, weigh nearly twice as much when green as when dry.

"If we assume the mean quantity of moisture in the woods when green, as 42 *per cent.*, the great disadvantage of attempting to burn wood in this state must be obvious; as in every 100 pounds of this compound of wood and water, 42 pounds of aqueous matter must be expelled from the wood, and as the capacity of water for absorbing heat is nearly as 4 to 1 when compared with air, and probably greater during its conversion into vapour, which must be effected before it can escape, the loss of heat must consequently be very great.

"The necessity of speaking thus theoretically, upon this point, is regretted; but it will be apparent that this question of loss cannot be solved by my apparatus, as the vapour would be condensed in the pipe of a stove, and the heat would thereby be imparted to the room, which, under ordinary circumstances, escapes into the chimney."

If we adopt the statement of Mr. Tredgold, that 8.40 pounds of Newcastle Coal will convert one cubic foot, or 62½ pounds, of water, into steam, under common pressure of the atmosphere, which is probably correct, Mr. Bull's table furnishes the remaining necessary *data* for a more accurate determination of the loss sustained in burning green wood. Take, for example, 100 pounds of green white oak, which Mr. Bull

found to contain 41 pounds of moisture: according to Mr. Tredgold, 41 pounds of water require 5.51 pounds of Newcastle Coal for conversion into vapour. Now we have the relative values of oak wood and Newcastle Coal, as it regards their power of producing heat, in the 10th column of Mr. Bull's table: 1 pound of white oak maintained 10° of heat in the room six hours and twenty minutes, and one pound of Newcastle Coal nine hours and twenty minutes. We have then this proportion; as 380′: 560′:: 5.51 : 8.12 pounds of dry oak, consumed in converting 41 pounds of water into steam; or, in other words, 13½ *per cent.* of the combustible matter of green oak is employed in boiling away its own water, and, in all ordinary cases, is a dead loss. It is true that arrangements might be made by a very protracted iron pipe, as in the stove used by Mr. Bull in his experiments, and other contrivances, for condensing the steam thus formed from green wood, and recovering both the latent and the sensible heat of the steam; but such an apparatus would be attended with too many inconveniences to be adopted in our dwelling-houses, and would be perfectly impracticable in large fires in the arts, where the flue is necessarily kept at a temperature above boiling water, and where, of course, the steam could not condense.

In the foregoing estimate of the loss of heat by the combustion of green wood, I have considered the subject in a theoretical point of view; or, at least, only in relation to those operations which have for their object the diffusion of heat in the air of apartments. But in most of the arts the object is the reverse of this,—to produce a strong and *circumscribed* heat. In these cases there is not only an entire loss of that portion of caloric which escapes in the steam from most fuel, (for it cannot be recovered, even if subsequently condensed, to any efficient purpose,) but if the temperature fall, in consequence of this loss of caloric in the steam, below the required point, there must be a total loss of the whole fuel. I suspect that it would be quite impossible for our glass manufacturers and iron founders to procure the intense heat required in their furnaces with the use of green wood. I have noticed at several glass-houses, and the practice is probably general, that the weather-seasoned pine wood is dried, or rather baked, by a stove heat, at a temperature that not unfrequently ignites it before it is used. I think it not unlikely that this practice might, in many instances, be profitably extended to the ordinary fuel (pine wood) used for steam boilers in our river boats; or, in other words, that a portion of the fuel might be economically expended in drying the remainder preparatory to use. Mr. Bull estimates the average quantity of moisture, in woods which have been weather-seasoned from eight to twelve months, at about 25 *per cent.*

of their weight. It may be objected to this suggestion, that although stove-drying may be indispensable where the attainment of a certain high degree of heat is absolutely necessary to the success of the process, yet where this necessity does not exist, the water may be as cheaply dissipated by the absorption of the caloric in the ordinary combustion, as by burning a portion of the fuel separately for that object. To this it may be replied, that the effective heat imparted to steam boilers is not, as is generally supposed, in a direct ratio to the quantity of caloric emitted by the burning fuel, but more nearly in proportion to the elevation of the temperature in the fire-place above that of the water within the boiler. The vapour formed by a fire that shall only elevate the temperature of the water to within a few degrees of the boiling point, say to 200°, bears a very small proportion to that which is produced at 212°; so that it is quite easy to burn a considerable quantity of fuel under a boiler to almost no practical effect. To pursue this subject into the causes of these results would lead to a theoretical disquisition on the laws which govern the communication of heat, foreign to the object of this work.

The great superiority assigned by Mr. Bull to the Lehigh and other anthracite coals, not only over wood but the best English coals, has also excited some doubt, and particularly with us at the north, of the accuracy of the comparison; but this, it may reasonably be supposed, is attributable to a mistake, against which Mr. Bull has warned us in his treatise, that of comparing his results with common experience derived from the very imperfect arrangements for the consumption of this fuel, both in the arts and in our dwellings. Its introduction is of too recent a date to have diffused correct information on this subject, and doubtless we have yet much to learn as to the best methods of applying it to many purposes in the arts.

"The composition balls of Lehigh coal, charcoal, and fire-clay," Mr. Bull observes, "were made for the purpose of ascertaining whether a very economical fuel might not be formed of the culm, or fine portions, of the two former, by combining them with the latter article, as they possess very little value: the same practice having been adopted with considerable advantage in various parts of Europe. The fire produced by these balls was found to be very clean and beautiful in its appearance. Its superior cleanliness is in consequence of the ashes being retained by the clay, and the balls were found to contain their original shape after they were deprived of the combustible materials. The beauty of the fire is enhanced by the shape and equality in the size of the balls, which during the combustion present uniform luminous faces. No difficulty was found in igniting, or perfectly consuming, the combusti-

ble materials, and the loss in heat, when compared with the combustion of the same quantity of each article in their usual states of aggregation, was found to be only three per cent." I think there must be an error, probably a typographical one, in carrying out the result of the combustion of this mixture in Mr. B's. table;—allowing the anthracite and charcoal to yield the same heat as assigned to them when burned separately in the aggregate form they should have sustained the same temperature only ten hours and twenty minutes.]

FURNACES IN GENERAL.

The principal, and most critical parts of the apparatus subservient to chemistry, being the furnaces employed for the preparation of those substances which come within the chemical class, the structure of these is more complex, and the uses they are applied to of a more nice and difficult nature, by far, than any other of the operations regarding that art. It is, therefore, necessary that they should be well designed, and judiciously executed. Otherwise their defects greatly enhance the expense, and frustrate the intention of the operations they are to perform; besides their being extremely liable to become, in a very short time, out of repair, and uselessly ruinous.

It is also proper that careful and able men should be employed in the fabrication of furnaces; though such are rarely to be found among common workmen. But the most likely to succeed are those who have either been employed before in the same business, or have been accustomed to set coppers for household purposes. When the best qualified, however, are set to work, they should be continually superintended by the operator, or some person capable of judging, both of their adherence to the plan given, and general performance of the work. For if the parts of furnaces, that are exposed to much heat, be not made extremely compact, but are patched up of mortar and bricks that are not fitted in every part to each other, as bricklayers are very apt to do from the habits they acquire by being employed in coarser buildings, the mortar will very soon calcine, and shrink, in such faulty places, and make such vacuities and inlets to the air, as render the furnace incapable of doing properly its office, to the great delay, and sometimes destruction of the process.

The materials are the next object of attention; and they ought to be well chosen, and perfect of their kind. Common bricks, with good mortar, made with lime and coal ashes, well mixed and beaten together, will serve for those parts which are not

liable to be heated red hot: but where that degree of heat, or a greater, may happen, Windsor bricks, and Windsor loam, or Stourbridge clay;* and where the fire may be very violent, the composition called the fire lute, hereafter mentioned, should be used. And as the Windsor bricks are of a texture which admits of it, they should be so ground to fit each other, as to form one compact body with scarcely any interstices at all.

Particular care should be likewise taken in the drying of furnaces. For the best designed or constructed may be easily spoiled by any mismanagement in this point; and this is very frequently the case. Where the use of them is wanted, as generally happens, before they are ready, they are not allowed a proper time. The interior part should be, therefore, suffered to settle and dry, for some days, before the cavity be closed in by finishing the upper; and after that part also is become pretty firm, they should be gradually warmed by a small charcoal fire, made either in the body of the furnace itself, or in the ash-hole under it. After this has been some time continued, and the mortar appears hard in the inward surface, a coal or wood fire may be made, of a gentle degree at first, and increased slowly, as the smoking of the furnace may indicate to be proper. But the more leisurely this proceeds the more durable and perfect will be the furnace.

Notwithstanding the great importance of commodious furnaces to the practice of chemistry and pharmacy, the methods in general used for their construction are surprisingly defective. Several errors committed with regard to them are here hinted. and on what principle they may be avoided; the remedy, however, in each case, will be reserved, till the improved plan for the construction of the several particular kinds is given.

"The first and most obvious fault is the disposing the fire-place in the front of the furnace, instead of putting it under the centre of the pot intended to be heated. By which means, the fire exerts its greatest force on the column of brick over it, calcining and destroying all that part of the furnace, without an equivalent effect on what it is intended to act upon. This improper disposition of the fire may, however, be easily avoided; and a right situation substituted, if the worm flue, improperly used in common, be omitted, and the other methods followed, which are given in the particular plans. And as the inconveniences resulting from this error extend as well to the fire-places of stills and boilers, as of other furnaces, an undue consumption of fuel, and quick destruction of the furnace, being always disadvantageous, it will be found beneficial to endeavour to remove them in all cases, especially as it may be done without producing any other incommodious consequence, except where immensely large vessels are in use, which unavoidably require a support of brick work under them.

"Another great error in the building of furnaces, particularly those for pots or stills, is, as has been hinted, the carrying the fire round the vessel to be heat-

* The clay obtained at South Amboy, N. J. answers the best purpose for fire bricks of any that I have met with in this country, but is inferior, I believe, to the Stourbridge clay.—Am. Ed.

ed, in a vermicular flue, or worm, as it is commonly called; by which means the vessel intended to be heated, is much longer in attaining a due degree of heat. As the principal force of the fire is exercised upon that great mass of brick-work which forms the worm, and is brought into equal contiguity with the vessel itself, in respect to the fire, with indeed a much greater surface exposed to it; from whence it requires a proportionable quantity of fire to keep the whole in any stated degree of heat.

"Besides the great delay, therefore, in the beginning of the operation, which cannot proceed till the whole mass, that makes the worm, be brought to a certain heat, the due effect cannot be had, without the consuming a much greater proportion of fuel than if the heated vessel hung in the open furnace.

"But there is yet another momentous inconvenience, arising from furnaces of this kind of structure, where a strong heat is wanted; which is, that the brick-work of these worms is extremely subject to be damaged, and fall to pieces. From whence, the flue being choked up, and the draught obstructed, a necessity arises of taking down all that part, if not the whole of the furnace, and rebuilding it at a great expense, as there is no possibility of repairing it under these circumstances.

"An entire open cavity carried round the pot, still, &c. formed by raising the brick-work, at an equal distance, on every side, and closing it in where no farther heat is required, answers the end much better. It suffers the proper object to be immediately surrounded by the fire, and places it out of the contact of other bodies, so as to be capable of being independently heated; while the furnace itself is much less liable to be damaged, or can sustain a small degree of damage, without any material injury to its use; and even when it is injured, so as to require repairing, admits of it with greatly less trouble and expense, than when built in the other method."

PRINCIPLES OF CONSTRUCTING FURNACES.

The importance of furnaces in the practice of chemistry is so great, that the principles on which they are to be constructed ought to be carefully studied, in order to be able to adapt them to the purpose the artist designs.

Furnaces consist of a variety of parts, namely; 1st, the twere, or entrance for air; 2d, a room to receive the ashes of the fuel; 3d, an ash-room entrance by which the ashes may be extracted; 4th, a grate to support the fuel; 5th, a fire-room to hold the burning-fuel; 6th, a feeding-door by which fresh fuel may be added as often as is necessary; 7th, a stoking-door by which the fuel is managed; 8th, the throat, or bridge, by which the flame and heated air are admitted into the laboratory or chamber of the furnace; 9th, the laboratory or chamber containing the vessels and materials to be acted upon by the fire; 10th, the entrance into or out of the chamber; 11th, the vent by which the flame and heated air passes out of the chamber into the flue of the chimney, and finally, 12th, the chimney to carry off the heated air and smoke into the atmosphere.

All these twelve parts are not to be found in every furnace, three of them only being essential to the very idea of a furnace; namely, the twere or entrance for air, the fire-room, and the vent.

The Twere.

The twere, or entrance for air, is generally made to open into the ash-room, but sometimes into the fire-room itself. When it is intended to admit the atmospheric air by the unassisted pressure of the latter, as in what are called air furnaces, it should be made as far beneath the level of the grate as the situation will allow. In some cases it is made to open out of a deep vault, or long subterraneous passage, or a hole being cut in the wall of the laboratory, an iron pipe is laid down so as to allow a current of cool air to flow from the outside of the laboratory into the furnace: the outer mouth of this pipe is frequently made conical.

The entrance of the air, in air furnaces, should in all cases be regulated, or, at the least, be capable of being stopped altogether, whenever it is judged requisite. Various methods are used for this purpose. The oldest, and, when the twere is not too large, still the best, is merely to heap up ashes against the twere, and to regulate the opening by means of a poker or spatula: at present, an iron door is more generally used, which is opened more or less as occasion requires. Some chemists use a series of circular holes, having their diameters in geometric progression, 1, 2, 4, 8, 16, &c., with stoppers fitted to them, as Dr. Black in his original furnace; others use one or two slides moving in grooves, and there is now sold in London a circular slide invented by Count Rumford.

In general the entrance for air in air furnaces is made much too large, so that the velocity of the air being diminished, it becomes much heated in its passage, expands, and thus a less weight of it is presented to the fuel. The area of the entrance ought to be regulated by the sum of the areas left open between the bars of the grate, and its area should not exceed two-thirds of those open spaces, in order that the air may strike against the grate with some degree of force.

Blast furnaces are those in which a larger quantity of air is supplied, by means of mechanical contrivances, than would pass through the fire by the unassisted pressure of the atmosphere. The air is made to enter the furnace by means of one or more pipes leading from the bellows or other blowing machine. In the small blast furnaces used by experimentalists, assayers, and other metallurgic artists, the twere is made no larger than barely to admit the blast pipe, and the crevices, if any are left, are usually stopped with soft clay; but in the large blast furnaces of the iron works this is not the case, and it is said that even in small blast furnaces there is some advantage in not being solicitous about closing the space between the blast pipe and the sides of the twere.

The Ash-Room.

In regard to the ash-room, no particular observations occur, except that in the small blast furnaces of the French experimental laboratories it is now divided horizontally in two parts by a plate of earthen ware pierced by a circular row of holes, the object of which is to equalize the blast of air, so that it may strike against all parts of the grate with equal force.

The ash-rooom is indeed frequently sunk into the ground in order that the other parts of the furnace may not be raised too high for the purposes for which they are designed, and hence is often called an *ash-pit*, although it may really be above the level of the ground. A proper ash-pit, if small, must have a sloping floor, that the ashes may be easier drawn out; or, if large, steps are made into it to allow the operator a free passage to the door. The cavity made by this slope, or the steps, is sometimes, as by the founders, covered over with an iron grating, or by a trap-door, with holes bored in it to admit the air. In this case, as the ash-room door could not be well got at, even if the furnace was provided with it, an iron plate, or loose board, may be used to cover more or less of the grating, or trap-door, and thus regulate the draught, or stop it entirely.

The Ash-Room Entrance.

The ash-room entrance is generally united with the entrance for air in air furnaces; but it is far better to have them separate, and to keep this entrance constantly shut by a door; and this the more especially, because it will very frequently happen that the position of the one is unfavourable for the other. Count Rumford's circular slide is usually fixed in an iron door for this entrance.

The Grate.

The grate is one of the most important parts of an air furnace. In small furnaces it is frequently of pig-iron, and cast in a single piece, but in the larger grates each bar is cast separate, and has a shoulder at each end, and sometimes when they are two feet or more in length they have also another shoulder in the middle, by which they are made to keep at a proper distance from each other. The bars are from one inch and a-half to three inches deep, according to their length, and about one inch thick: they are put in so as to rest loosely upon bearing bars, placed across the top of the ash-pit, that they may be taken out easily, and renewed if it be necessary.

In the furnaces intended for boiling water, or a similar heat, a distance of half an inch between the bars is sufficient. In

those for greater heats, as in distilling, with earthen retorts or iron cylinders, the distance should be about three-quarters of an inch, and in melting furnaces, a full inch.

When furnaces are used to heat steam boilers, brewers' coppers, stills for ardent spirits, or evaporating pans in salt works, alum works, or the like, the grates are usually made of greater extent, in order to expose a large surface of the heated fuel, even to the extent of four or six feet square, and it is computed, that with half inch spaces between the bars, each square foot of the grate will consume about eleven pounds of Newcastle coal every hour. Now, although these large grates are laid sloping down towards the back of the furnace, at an angle of twenty, or even thirty, degrees, or with a fall of from five to seven inches and a-quarter in each foot, yet there is a difficulty of spreading the coals equally over the surface of such large grates; and the coals also run into large masses of clinkers, which are very troublesome to extract out of the fire.

When the purposes for which a furnace is constructed are such that a small fire is required at one time, and the heat must be vehement at another, Dr. Bryan Higgins used loose iron bars, an inch square, instead of a grate. For a moderate fire, so many of these bars were placed upon the bearing bars fixed in the walls of the furnace, as to leave interstices of half an inch between them: when the fire required to be increased, one or two of the bars were withdrawn, and those left on the bearers arranged at equal distances by the poker. If by chance any accident happened which required the fire to be suddenly stopped, the whole of the bars being withdrawn, the fuel descended at once into the ash-room.

The Fire-Room.

In respect to the fire-room, the principal care is to surround it with those substances which conduct heat the slowest, in order to prevent the fuel being expended in waste. The side walls should, therefore, be double, with a space of about two inches and a-half between them; the two walls being tied together, as the bricklayers express it, by bricks from space to space, and this may either be left empty or filled with ground charcoal or coke.

[Wood ashes are preferable for this purpose; its non-conducting powers are nearly equal to those of charcoal, and it is not liable to be burned out by exposure to the air through the chinks, which are constantly occurring in the walls of furnaces, which are subjected to high heats.]

The inner wall must be constructed of such bricks as will bear the action of fire without running into glass; and these

be set in an argillaceous cement of a similar nature, and ıonly called fire-lute.

e fire-rooms of portable furnaces, which in England are y made of iron plate, are, in like manner, lined, next the with charcoal powder made into a consistent mass with water, and next the fire, either with fire bricks, fire-lute, nixture of charcoal or coke powder, with any clay that ear the fire. Sage has recommended asbestos ground and l into a paste, with the mucilage of gum tragacanth, for the osition of portable furnaces.

ith a view to avoid both the inconveniences lately men- l as incident to large grates, Mr. Losh, of Point Pleasant, umberland, in a patent which he took out in 1815, re- ends for furnaces of the kind there mentioned, the use of r more, even as far as six grates, with as many separate ooms; and he avers that from his long experience in the gement of a large chemical manufactory, that this plan is ded with a great saving of fuel, and the boiling, generation am, distillation, and evaporation, goes on in a more equa- anner; and also that the manual labour of the stoker is derably less when several small fires are used to heat these pots, than when only a single immense fire is to be mind- To which there may also be added the facility of repair- ıe fire-places without stopping the operations.

ere is another view with which two grates, and as many ate fire-rooms are constructed under large boilers. These ces require a copious supply of fuel, which is generally oal, and emits of course a large quantity of black smoke time a fresh supply of coal is put upon the fire, to the annoyance of the neighbourhood.

ith a view to get rid of this inconvenience two plans have adopted. Mr. Watt, in 1785, constructed a small second oom and grate between the principal fire-room and the ney, in which he kept a small fire of cinders, coke, or ıer clear burning fuel, in order that the smoke as it passed this clear fire might be burned; but this plan has not been to answer completely, as the necessary supply of air for ombustion of the smoke could not be supplied through this secondary grate.

tely, Mr. Newman has proposed another somewhat simi- nstruction. He builds two fire-rooms and grates side by which communicate with each other; each of these fire- s has a vent into the chimney, which can be opened or ed at pleasure. Supposing, then, a fire is made in both ooms, and the vent belonging to the fire-room A is open, hat of B shut, the smoke generated on adding fresh fuel will have to pass over the surface of the fire in A, and

thus be burned for the most part in its passage. The next parcel of fuel is to be supplied to the fire-room A, and for this purpose the vent of the fire-room B is to be first opened, then that of A closed, and lastly the fuel supplied; the smoke from which will then be obliged to pass over the surface of the fire in B. In this alternate mode the two fires are to be supplied, and the smoke from the one made to pass over the other.

Stoking Hole.

A stoking hole is necessary in furnaces for lighting the fire, and extracting the clinkers that are formed. For the convenient performance of these purposes this hole must be on a level with the grate or nearly so; and if the grate is formed of loose bars, which are to be occasionally pulled out or put in, as a greater or less degree of heat is required, it should descend a little below the grate to give room for this purpose.

This hole is generally closed by an iron door, lined with clay or a piece of fire-stone. For the purpose of ascertaining when the fire wants stirring or replenishing, a hole, about an inch in diameter, and covered by a piece of iron, which hangs loose by a rivet above, is sometimes made in this door.

Feeding Hole.

The feeding hole, by which fuel is supplied to the fire-room, is usually on the side a little above the height to which the fuel reaches, but sometimes on the top of the fire-room. It should be made large, that a considerable quantity of fuel may be added at once, and thus the frequent opening of this hole, and the consequent cooling of the interior of the furnace, be prevented.

This opening is very often closed by means of a door hung on hinges, or sliding up and down, being supported by a counter weight; sometimes a stopper is used, but these are apt to stick; the door or stopper is usually made of iron and lined with fire-lute, or in small furnaces the stoppers are made of clay.

Sometimes what is now called a *hopper* is used, which is made of cast-iron plates, and set rather sloping in the furnace. This being filled with coal has its outer end stopped up with small caking coal, and as the fuel in the fire-room is consumed that in the hopper is pushed in to supply its place; care being taken respecting the keeping of the outer end stopped by the small coal.

Even in this method of feeding the fire, cold air is necessarily admitted, and the interior of the furnace cooled in consequence; so that, although hot air be admitted into the chamber, yet the smoke will not take fire until sometime after the coals have been added.

To avoid this inconvenience close hoppers have been contrived with a moveable bottom, formed either of a sliding plate, or one moving on a hinge, and held up by a counter weight equal in effect to the weight of the coal contained at any one time in the hopper, which is closed at top by an iron lid shutting very close. This close hopper, being built in the furnace directly over the fire-room, or, at least, the front part of it, is filled with coal, the lid shut down, and when the fire wants replenishing, the bottom is opened, and the coal of course falls down on the fire, without the introduction of any cold air to cool the interior of the furnace.

When this mode of feeding is adopted, it will be adviseable, just before the letting fall of the fresh coal, to push that already in the furnace towards the back, by means of an iron hoe, as wide as the fire-room, and about four inches deep, with a long iron handle passing through a hole in the bottom of the stoking-door, and which hoe remains constantly in the furnace, being pulled up close to the stoking-door, before the fresh coal is let fall.

A feeding hole, distinct from the stoking hole, is seldom used in England, notwithstanding its advantages were set forth by Mr. Dossie, in his "Elaboratory laid Open," fifty years ago. He very justly observed, that if the fuel can only be thrown in at the stoking hole, there exists a necessity for having the area of the fire-place large, since otherwise a sufficient quantity of fuel cannot be made to lie upon it. For if the grate be small, the coals tumble out, whenever it is filled to any great height, every time the door is opened.

Now the disadvantages consequential to the having the fire-place too large are manifold. For if the space, occupied by the bars, be great, and the whole area they make, be covered with coals, the heat will be too strong on many occasions.

If the whole area be not covered, a false draught is made through the uncovered part, which greatly weakens both the degree and effect of the fire proportionably to the quantity of fuel. As the influx of the air will be the greatest through the naked part of the area, which much weakens the draught through the coals, at the same time, it greatly refrigerates both the furnace and its contents; so that not only a great waste of fuel is in such case made, but the latitude in the degree of heat, and means of accommodating it to the occasion, which are to be completely had in furnaces well constructed, are hereby greatly limited. This defect may, he observed, be remedied, by making a proper feeding hole, sloping slightly towards the fire, some inches above the surface of the fuel, when at the highest.

Through this hole the fire may be fed by a shovel of a fit size and figure, or stirred with a poker, properly bent, without

using the door for those purposes, which need, therefore, only be opened for the making or lighting the fire, or freeing the bars from the scoria or clinkers, when they are choked up with them.

This manner of feeding the fire will be found a very great convenience to those who are accustomed to it. As the effectual draught of the furnace may be thence greatly increased, the lighting the fire much facilitated, and the operator likewise enabled to have what body of fuel he pleases in the furnace, and to adequate the heat with certainty, to any occasion, without either being subject to have the fire extinguished, when it is kept low; or not to admit of being raised high, with the falling out of the coals, already in the furnace, every time he attempts to throw in a fresh supply.

When this device is used, the usual area of the bars may be diminished at least one half; and the consumption of fuel will be lessened much more than in that proportion, for the reasons before given. The operation will not be soon checked, on any neglect in keeping up the fire, which is liable to happen, when furnaces are built in the common way.

The Throat.

In many furnaces there is no visible throat between the fire-room and chamber; the walls of the two rooms being continued in a line. In some, however, the separation is very distinct, and the throat is either a simple opening, the lower limit of which, when on the side, is usually called the bridge, or instead thereof, a number of small holes disposed, generally, in a quincuncial order, or chequer-ways, by which arrangement the distribution of the heat through the chamber is rendered more equal than when only a single opening is used. In this case, care must be taken that the sum of the area of these holes shall not exceed that of the free space between the bars of the grate, otherwise the desired equal distribution of the heat cannot be obtained.

The Chamber.

The situation of the chamber varies much, and gives certain denominations to various furnaces. In some furnaces the chamber and fire-room are united; and even in this case there are several variations: for sometimes the substances to be acted upon are mixed with the fuel, and that either in alternate beds, one on the other, as in lime and brick-kilns, or the fuel and the other materials are thrown alternately in at the mouth of the furnace, as in the blast-furnaces in which iron ore is smelted. In other furnaces, the vessels containing the materials are either placed circularly round the fire next the well of the fire-

room, as in glass-house furnaces, and those in which spelter is distilled and brass made; or else the vessel is placed in the centre of the fire, and entirely surrounded with fuel on the top as well as on the sides, as in the furnaces of founders and casters of metals: this latter disposition has received, amongst practical writers, a peculiar denomination, namely, that of a wheel-fire, or ignis rotæ.

The chamber, when it forms a separate part from the fire-room, admits of three variations; for sometimes it is over the fire-room, sometimes on the side, and sometimes it is placed in the centre, and surrounded with several fire-rooms.

The chamber is placed over the fire-room in the furnaces used with pots, kettles, common stills, and the boilers for producing steam. These vessels in general hang down from the mouth of the chamber, which is placed directly over the fire-room, and there is a sufficient space left between the vessel and the walls of the chamber, to allow the free passage to the vent of the air that has passed through the fire. The breadth of this space is usually left to the judgment of the bricklayer; the horizontal area of it ought to be equal to that of the free space between the bars of the grate, which is the radix from whence all the proportions of the different parts of a furnace are to be calculated. Hence, if it be required to determine the space to be left between the outside of a cylindrical pot, boiler, or still, and the wall of the furnace, first find the area of the horizontal circular section of the vessel, measured on the outside, by any of the methods in use for that purpose, (which may be seen in Mr. Nicholson's Operative Mechanic, page 694, or any treatise on Mensuration;) and to this area add that of the free space between the bars of the grate, the sum will be the area of the circle to be formed by the internal side of the wall; the diameter of which being found, the difference between this diameter and that of the vessel being halved, will be the breadth of the space to be left between the vessel and the wall of the furnace.

In these kinds of furnaces there is seldom any contraction, or throat, between the fire-room and the chamber in which the vessel hangs. Curaudau has proposed to throw an arch over the fire-room, with a circular opening in the centre, and affirms that by thus contracting the space to which the full force of the fire is first applied to the vessel, it produces a more powerful effect; but there also arises this inconvenience, that this part of the vessel is liable to be burnt out before the other parts, so that frequent renewals of the vessel are requisite. When indeed the vessel is very large, it requires to have its bottom supported by pillars of masonry, so disposed as to allow a free passage for the air that has passed through the fire to get to the vent.

Furnaces with chambers over the fire-room are also used by

tobacco-pipe makers, and in the potteries: in these furnaces the roof of the fire-room is pierced with several holes, that the heat may be distributed as equally as possible through all the parts of the chamber.

In the furnaces used for roasting ore, and smelting them, as also in certain other operations, as in baking porcelain ware, the chamber is placed on one side of the fire-room. The communication in these furnaces is usually made by a single opening, but sometimes a series of holes are used. The larger furnaces used by the potters have a large central chamber, with four or six fire-rooms surrounding it, and opening into it by as many single openings. The metallurgists also sometimes use a central chamber with a fire-room at each end.

Many contrivances have been adopted for the purpose of introducing a supply of fresh air into the chambers of furnaces to consume the smoke, which is emitted in such quantities every time the fire is supplied with raw pit-coal. A direct entrance into the chamber has the disadvantage of cooling it considerably, and is therefore not adviseable in any circumstances, and in addition to this the smoke itself is not thoroughly consumed by this method.

Several patentees have made channels in the masonry of the furnace leading from the top of the ash-pit, near the grate, into the chamber; and some have furnished these channels with sliders. Others have made channels in the walls of the fire-room, opening at one end to the external air, and at the other into the chamber. The object of these patentees being to supply the fresh air in a heated state, that it may accend the smoke, and thus cause its consumption; but, as the furnace is always considerably cooled every time the door is opened to supply coal, the smoke is sometime before it will burn.

A still more powerful method of effecting this object has been lately proposed by Mr. Chapman, of Whitby. He causes the bars of the grate to be cast hollow, and when set in the furnace they open into two boxes, one placed in front and the other behind the grate. In the front box, which is of course directly under the stoking door, he has a register to admit more or less air at pleasure. The box behind the grate opens into an empty space, which is formed by making the bridge of the furnace double. Hence, when the register of the front box is open, there is a great draught of air through it, along the interior of the grate bars, thence into the space between the two walls of the bridge, and out of the slit at the top, where it comes in contact with the smoke, and as soon as the cooling of the furnace, by the opening of the door is overcome, causes it to inflame and become a sheet of bright fire under the bottom of the boiler; but when a close hopper is used, and the

introduction of cold air prevented, the smoke is entirely consumed from the first.

Opening into the Chamber.

An opening into the chamber is required in almost every case. This is very commonly at the top, being a circular hole, in which the pot or still is hung. Sometimes it is on the side, as in those called English reverberating furnaces used for roasting and smelting ores, or in potters' kilns.

It is seldom that these openings into the chambers have doors adapted to them, as they are closed either by the vessel, as in the first case just mentioned, or they are filled up at the commencement of each operation by means of slight brickwork, which is removed when the operation is performed.

Sometimes the opening into the chamber is left open, and actually serves in some cases as a vent, the usual vent being stopped.

The Vent.

The vent of the furnace has given rise to much difference of opinion as to the size it ought to have. Some make it large, to allow a freer passage for the burnt air into the chimney; others again small, that the heat may not be dissipated and carried up into the chimney in waste.

It is generally a single opening, but in porcelain furnaces, the manufacturers use a number of small openings instead of a single vent, with the view of assisting in the equal distribution of the heat throughout all parts of the chamber: and this practice should be adopted whenever this equal distribution is requisite. These artists are also careful that the sum of the areas of these holes should be exactly equal to that of the throats by which the flame and heated air enters into the chamber.

It seems, therefore, adviseable in all cases to make the vent or vents equal in area to that of the free space left between the bars of the grate.

The situation of the vent is usually at the top or back of the furnace; but there results a very great inconvenience from its being situated in the latter position; since, when the feeding or stoking-doors are opened to supply fresh fuel, or manage the fire, a strong indraught of cold air takes place, which rushes over the surface of the fire, and not only cools the whole interior of the furnace, and prevents the accension of the vapour from the raw fuel, thus causing the production of smoke and soot, but also cools the vessels and materials exposed to the action of the fire; and when the vessels are made of glass, pottery ware, or cast iron, frequently cracks them, unless they are defended by a thick coating of lute, which necessarily di-

minishes the heat that can be applied to the materials contained within them.

Mr. Losh, already mentioned as a considerable improver of the construction of furnaces, has therefore proposed to remove the vent to the front of the furnace, immediately over the feeding or stoking-door, and to conduct the burned air, through channels made in the masonry, into the flue of the chimney. A great advantage attends this construction, that when either of the entrances into the fire-room are opened, the indraught of air, instead of rushing over the surface of the burning fuel and striking against the vessels and materials, instantly passes up the vent, and does not enter at all into the interior of the furnace, whence this is much less cooled than in the furnaces of the usual construction.

As the entrance of air into the furnace is regulated by sliders and other contrivances, so in many furnaces, where this is neglected, its outlet is regulated by a damper or slider placed at the vent, by which its opening into the flue is altered at pleasure, and may be even stopped entirely: but it is far preferable always to have a door to the ash-room, or entrance for the air, and regulate the fire by it.

The Chimney or Flue.

The chimney or flue is one of the most important parts of a furnace; and yet, in general, the least attended to; being usually made much too large in its horizontal area. By making it thus large, the draught through it is much diminished, and the soot collects and becomes troublesome. For when the sides of the flue contain a larger surface than can be duly heated, the necessary rarefaction of the air passing through it is destroyed. On this principle alone the draught of chimneys depends; and the cavity being too large proportionably to the current of air, the force of it is so diminished that the soot, instead of being blown out, gathers and rests on the sides till it obstructs the passage, and choking up the draught deadens the fire, especially at the first lighting of it; by which means the progress of the operation is sometimes greatly retarded. Instead, therefore, of the large proportion now made use of, if the chimney be intended for the use of one furnace only, an area equal to that of the free space between the bars of the grate is fully sufficient; and this may be increased in proportion where it is designed for a greater number.

The reverend Mr. T. Ridge has observed, that if a recess is left at the bottom of the flue, below where the vent of the fireplace enters it, the soot collects in this recess, and the fouling of the flue is proportionally prevented.

This recess or well might have an opening made into its low-

:r part, which being opened occasionally, the soot might be ex-:racted without the necessity of ascending the flue.

It is well known that when flues are carried horizontally, for he purpose of connecting a furnace with the upright shaft of ı chimney, they fill very fast with soot, the draught through them can scarcely be maintained, and they are even apt to burst. On adding a recess on this principle to a horizontal flue, all the soot collected in the recess, and the flue was scarcely soiled.

A single flue is sometimes made to serve for several furnaces, which is advantageous when a number of furnaces are in constant action, so as to keep the mass of the chimney at a sufficient heat that the ascensional force of the air which has passed through the fire is not diminished by cooling. But unless this condition can be maintained, separate flues for each furnace will be most advantageous.

All the furnaces attached to a single flue, which are not in use, must be kept close shut up, or, at least, the dampers at their vents, if they have this apparatus, closed, otherwise a false draught will take place, and the cold air passing through them will cool the flue and diminish the heat of the furnaces that are in action.

The stability of the chimney against the action of the wind, when it stands separate from other buildings, requires that it should have a sufficient breadth of base. The calculations of Mr. Tredgold, in the supplement to the Encyclopædia Britannica, show that each side of a chimney, having a square basis, or the narrowest side if the basis be rectangular, should be at the least one foot in breadth for every ten feet in height; and the area of the flue ought not to exceed one-third of the area of the chimney.

The chimneys of our common domestic fire-places have their upper terminations enlarged, by the addition of a circular chimney-pot, which circumscribes their square flue. This enlargement is vulgarly, but erroneously, called a contraction, by those who look only to the external appearance without considering the greater thickness of the brick-work in respect to the sides of the pot; and is supposed to increase the draught of the flue.

With the same view, the chimneys in Venice are terminated by pots which are of a conical form, much wider at top than at bottom. From the experiments of Venturi, on the flowing of fluids through pipes, it would appear that this construction was preferable to our own chimney-pots, which are, on the contrary, rather narrower at top than at bottom. In describing the fourneau lithogeognosique of Dr. Macquer, an occasion will be had to relate an experiment of M. Guyton de Morveau, relating to adding a conical flue widening at top to the furnace.

When the chimney has attached to it furnaces which give a great heat, and of course have a strong draught, the ascensional force of the heated air will overcome the action of the wind, unless it blows a perfect storm. But in chimneys attached to furnaces of no powerful action, the wind frequently prevents the exit of the burned air, and thus diminishes the power of the fire. Hence all chimneys should have the top of their side walls sloped upwards from the outer surface to the inner, in order that the wind impinging on the top may be deflected upwards, and thus assist in drawing out the smoke and burned air.

The wall of chimneys is usually single; but when the air which passes up the flue is very hot, it has been found preferable to have the wall double, with an empty space left between the two, which are tied together from space to space by bricks passing from one to the other.

Velocity of the Draught.

It might be supposed that the velocity of the draught through furnaces would long ere this have been reduced to calculation. Yet this is not the case, and the various measures of it by the several mathematicians who have investigated the subject, differ in an astonishing degree. They all, indeed, proceed upon the principle of the acceleration of velocity in falling bodies, and the usual theorems of hydrodynamics, but vary very considerably in the application of them.

The mathematical investigation of this apparently simple question may be divided into two classes. Most of them found their calculation on the compound ratio of the acceleration produced by the height of the chimney, and of difference in specific gravity between the external air of the atmosphere, and that in the flue of the chimney; and yet, even these do not agree in the results they obtain. On the other hand, Mr. Davis Gilbert, whose fame as a mathematician of the first rank is unimpeached, stands alone, as he grounds his calculation on the velocity with which atmospheric air rushes into a vacuum, or any medium of less density than itself.

They equally differ as to the place where the temperature of the heated air shall be taken to compare with that of the atmosphere: as the generality of writers take the temperature from the top of the chimney where the heated air rushes out into the atmosphere: while Mr. Davis Gilbert in this point varies from his brethren in choosing the temperature of the hottest part of the furnace for the ground-work of his calculation.

Taking, then, as an example, a furnace adapted for melting copper, with a chimney forty feet higher than the half, or average height of the entrance for air; the temperature of the hot-

of which is 1500 degrees of Fahrenheit, that of the air
rom the chimney 123 degrees of Fahrenheit, and that
xternal air forty degrees of the same scale. If we cal-
e velocity according to the principles of M. Montgol-
is the first author who investigated the subject, as they
lown by M. Payen in the Dictionnaire Technologique;
that the draught is equal to the velocity that would be
by a heavy body in falling through a space equal to
le difference of the height of two similar columns of air
upon the same base; the one of the air of the external
ere, and the other column of the air in the chimney, of
height when hot, but reduced by cooling to the tem-
of the atmosphere. Now, according to this hypothe-
eated air will pass out of the chimney with a velocity
t .91 in each second of time.
er mode of calculation has been given in the article
, in Rees' Cyclopædia, grounded upon Mr. Atwood's
which leads the writer of that article to divide the
e of the specific gravity of the heated air and external
eir sum, the quotient multiplied by the velocity which
body would acquire, by falling freely through the
the chimney, will, it is said, give the velocity of the
f air through the flue. But this velocity will, the wri-
s, be double the real velocity, on account of the re-
which the current experiences by the friction against
of the flue. Now, if this mode of calculation be pur-
velocity of the air issuing from a furnace of this kind,
feet .88 in a second of time; so that if the half of this
d velocity be taken for the real velocity, it will be 1

g over, for the present, the calculations of Mr. Davis
as being founded upon a totally different hypothesis,
author who has considered the subject is Mr. Sylves-
he Annals of Philosophy, for June, 1822. He refers
Davis Gilbert's calculations, and conceives that the hy-
on which he proceeds must be erroneous, because it
for its result a velocity which far exceeds that of
odies falling freely in a vacuum, whereas the resistance
edium must produce some retardation of this velocity.
ding to Mr. Sylvester, the velocity of the current of
ir will be equal to the difference between the specific
of the cold external, and heated internal air, divided
ecific gravity of the cold external air, and the quotient
ed into the acceleration of velocity that would be ac-
y a body falling the height of the chimney. Whence,
receding data, the velocity would be 7 feet .74.
recent work, written by Mr. Tredgold, he has given

very elaborate formulæ for calculating the draught of ventilating pipes, and the chimneys of furnaces. He assumes the force whereby the current ascends, to be equal to the height of the chimney, multiplied by the expansion the air suffers from the increased temperature to which it is subjected. And that the velocity is equal to the square root of sixty-four times the force; from which velocity, three-eighths, or even one-half, must be deducted on account of contractions, eddies, bends, and friction.

Now, on this hypothesis, the theoretical velocity of the current of air in the flue of a furnace of this kind will be equal to 18 feet .9; from whence, deducting one-half, the actual velocity is probably nine feet and a half.

Hence, although these mathematicians all proceed upon nearly the same theory, still great discrepancies exist in their results.

According to Montgolfier's calculation, the velocity of the draught in every second of time, is - -	13 ft.	.91
The writer in Rees' Cyclopædia - - - -	1	.94
Mr. Sylvester - - - - - - - - -	7	.73
Mr. Tredgold - - - - - - - - -	9	.50

But these differences vanish entirely before the calculation of Mr. Davis Gilbert, in the Quarterly Journal of Sciences for April, 1822. According to this gentleman, the rarefaction or expansion of the air by the heat being ascertained, by raising the fraction $\frac{48}{480}$ to the power whose index expresses the difference of temperature, and the density or specific gravity of the burned air, as compared with that of the external atmosphere, which Mr. Gilbert states at 1.0874 to 1, the expansion divided by the specific gravity of the burned air, will show the specific gravity of the air within the chimney.

The tendency to ascend will, he says, be equal to the difference between this specific gravity and that of the atmosphere, multiplied by the quotient obtained by dividing the height of the chimney, by the height the atmosphere would have, if it were of uniform density throughout, which is assumed, by Mr. Gilbert, to be 26058 feet. The square root of this product is to be multiplied by the velocity with which the atmosphere would rush into a vacuum, namely, 1295 feet in a second of time; and the product divided by the square root of the specific gravity of the lighter air will give the velocity.

Now, according to this hypothesis, the velocity of the air passing through the above-mentioned furnace, would be no less than 225 feet .67 in a second of time; which being equivalent to 153 miles in an hour, is about five times the velocity of the wind in a full storm.

It would appear from the immense discrepance between these calculations of the velocity by the most eminent mathematicians,

that every attempt to reduce the question to mathematical calculation, has hitherto proved utterly abortive, and has left the subject in as much obscurity as ever. Thus much seems certain, that if any smoking or fuming body be held near the entrance of the air into a very powerful melting furnace, when in full heat, the velocity with which the smoke or fume is drawn into the furnace, seems by no means so rapid as might be expected on the calculation of Mr. Davis Gilbert.

Mr. Haycroft observes, that the heat in blast-furnaces does not increase merely in the ratio of the fuel consumed, but in some compound ratio: and that even in air-furnaces, those through which the greatest quantity of air passes in a given time, consume a proportionably less quantity of fuel to produce the same effect.

Annoyance of Smoke.

It has been already seen how many contrivances have been had recourse to, for preventing the annoyance of the smoke so plentifully emitted by raw pit-coal, when suddenly heated without the contact of a sufficient quantity of heated air; and to this nuisance there are frequently superadded those of arsenical and sulphureous vapours, volatilized metals, and other matters, which spread widely around the works wherein they carry on the smelting of metals.

In the German mineral works, a long and large horizontal flue is interposed between the vent and the ascending flue of the chimney, in which the arsenical vapours are condensed, and collected for sale; but this is not always practicable, nor would it be always sufficient.

Mr. Jeffreys, of Bristol, has proposed a plan for avoiding this nuisance of arsenical fumes, and which may also be employed to condense and collect the smoke. His plan is to build two flues, either contiguous, or at any distance from one another, but connected at the top by a horizontal flue. The second flue is covered with a cistern, whose bottom is pierced with a number of small holes, like a common cullender; and this second flue has at the bottom an opening on the side to let out the water that runs down it.

Now, when the furnace is used, water is let on to the cistern at the top of the descending flue, which immediately runs in small streams through the holes in the bottom, which divide into drops as they fall, and carrying down air with them, produce a considerable draught through the flues, differing from the draught produced by bellows, or ordinary blowing machines, by being applied behind the fire, and drawing, instead of pushing the air through it.

This shower of water, as soon as it intermingles with the smoke and vapour of the fire, also immediately condenses and mixes with them, carrying them down, so that they run off with it through the opening at the bottom of the flue.

The efficacy of this mode has been completely established by experiment. The draught of air through the furnace was prodigiously increased; and although the ascending column of smoke was rendered as dense and black as it could well be made, yet not a particle of smut or smoke was observed to escape by the vent at the bottom of the water flue. A strong current of air, and a stream of black water issued forth, but nothing like smoke.

Though advantage may be derived in various ways from the application of this invention, and more especially where the expense of carrying it into effect bears but a small proportion to the advantages that will accrue; still it may be expected that many instances will be found in which the difficulty or expense of procuring the necessary supply of water, and possibly other causes, will operate as a total bar to its adoption. On the other hand, it is not improbable that time and reflection may discover remedies which, at the outset, may not occur: thus, when the furnace is used to heat a steam boiler, a part of the power may be expended in raising water for this purpose.

Conical Dome.

In some chemical works the laboratory itself is the real chimney of the furnace, and is used to produce the necessary draught, as in glass-houses and potteries. In these manufactories, a large conical dome surrounds the furnace at some distance, so as to allow the workmen free access to it. This dome is carried to a considerable height, and surmounted at top by a short cylinder. The air then being admitted into the furnace from a vault under ground, passes through the fire, and out of the fire-room or chamber into the dome, by several openings above the level of the workmen's heads; and as no more air is admitted into the dome by the doors than is absolutely necessary for the respiration of the workmen, the fire receives nearly the full benefit of the velocity of draught produced by the height of the dome.

Chemists have sometimes endeavoured to imitate this construction in their small experimental laboratories, when they had only a wide recess with a single flue, like those formerly used in English kitchens, and still in farm-houses, for their chimney. To obtain a great degree of heat in their wind furnace, although its proper chimney rose only two or three feet high, they fitted a pipe of three or four inches diameter to

the ash-room of their furnace, and passed the other end through the wall of the laboratory; this end was sometimes widened into a kind of funnel.

As mere practical chemists have seldom much knowledge of hydrostatic and pneumatic theories, many have complained that they did not receive the benefit they expected from this air-pipe. This was because they neglected the necessary conditions for its proper action: which are, first, that the ash-room door be closely stopped so that no air may pass the fire but what comes through the pipe; secondly, that the windows and doors of the laboratory be accurately closed, and even paper pasted over the crevices to prevent any entrance of air through them, to create a false draught up the chimney; and lastly, that the door be not opened during the process, unless the operator be much distressed in his respiration, and then only for a moment. By these precautions being taken the laboratory becomes a part of the chimney, and the full effect of its height is produced.

Blast of Air.

The introduction of a blast of air into furnaces, instead of depending upon their own draught, is used when it is not convenient to construct a chimney of sufficient height to produce the intended effect, or when it is desired to obtain this effect in a shorter space of time than would be required in air furnaces; as these last take a considerable time before they attain their full draught, by the mass of masonry, of which they consist, carrying off a considerable portion of the heat, until it becomes so well heated as to require no farther addition, except to supply that portion which passes through the walls themselves.

Two methods have been employed to produce this artificial blast. The oldest is probably the water blast, or that produced by the air, which is carried down by a shower of water made to fall a sufficient height. As this fall could not always be obtained where a blast was wanted, recourse was had to bellows of various construction, and blowing machines.

On both these methods the blast, as originally produced, is more or less unequal, and requires regulation. Three modes are used for this purpose: in the one the blast as it issues from the machines is introduced into a chamber of very great size, either constructed of iron plates, or masonry, or cut in the substance of a rock, by which means the unequal blast of the machines is equalized, and it issues out at the other end in a regular stream.

In the second method, the blast is thrown into a vessel with a moveable top, sliding up and down in it at pleasure, it being

kept horizontal by an iron standard or rod, rising from its centre and passing through a hole in a cross piece fixed above the vessel: this sliding moveable top is loaded with as much weight as is judged necessary. The blast then being sent into this regulator, as it is called, raises the moveable top, and the weight placed on it regulates the strength of the blast.

In a third method, the blast is first thrown into a large vessel of wood or iron plates, opened at bottom, closed at top, and fixed in a large cistern of water. Here the water, being driven out by the blast, rises in the cistern, and by its pressure regulates the blast to the furnace.

Provision to be made.

Previous to *building furnaces*, it is necessary to provide the iron work necessary in their construction, that no delay may take place.

An iron door with its frame, for the lighting of the fire, and taking out the *scoria* of the coals, is requisite for most kinds of them; but, as such doors are commonly intended for the farther use of feeding the fire with fuel, they are made much larger than is necessary. If that method be not used, it is yet proper, always, to have them as long as the fire-place, or area made by the bars. They need not, however, for ordinary furnaces, be more than four inches high, where they are not designed to serve for feeding the fire. For, the lower they are, the less they will be capable of injuring the proper draught of air through the fuel, by making a false one; and the less liable also they will be, themselves, to warp and be out of order. They should be made of hammered iron, lined with a plate of cast-iron well riveted to the other. The usual form will very well serve, if the latch to keep them shut be made bigger than common, and carried across the whole door, to give it strength to resist the weight of the fuel, which otherwise, when the iron is softened by violent heat, forces the middle part outwards.

A proper cast-iron frame is necessary to be provided, for the hole through which the fire is to be fed with fuel, when that method of doing it is followed. The frame must be made of the size and form of the hole, which, in middling-sized furnaces, may be four inches wide and three high, or bigger where the furnace is large. The bottom plate should project six or eight inches beyond its joining with the side plates, and be four or six inches wider, in order to form a slab, on which the stopper, or stopping-coal, may be laid. This stopper is usually a brick, which does full as well as any other thing. The frame itself may be merely a slab of cast-iron, about a foot square, or even a tile of that dimension, and the top and sides formed of wrought-iron bars, bent into the proper form.

Plates and broad bars are also generally wanted, to be laid where brick-work is to be raised over the hollow parts of furnaces. Where larger plates are required, the cheapest and best way is to have them cast of the exact dimensions wanted. But, when a broad bar or two, laid together, will answer the end, the easiest way is to have them cut off of a proper length, from the bars of hammered iron, at the ironmongers. The right proportion of them may be easily computed, by estimating the proportion of the parts of the furnace they are to be subservient to, which should be always carefully done; and the workmen should be apprized, by written instructions and drawings, of the size and measure of every thing they are to erect or put together.

In chemical manufactories, the proprietors should contrive to continue their processes night and day, or if that is not practicable, they should stop all the openings in the furnace so close as to prevent the furnace from cooling during the night. Furnaces thus kept constantly hot, will last six or seven times as long as those will do which stand frequently idle. The contraction of the ma-

terials during the time of cooling, alternating with their expansion when they are again put into use, wear them out very rapidly.

When this continual use of the furnaces cannot be adopted, some chemists, in order to make them last longer, bind them with iron bars, either screwed together, or fastened by loops and wedges; others, taking advantage of the cheapness of cast-iron in England, enclose them in cases of that metal, cast for the purpose, with proper openings; the several parts of which case are screwed or pinned together.

For common furnaces, thin flat bars of tough iron, about eight inches longer than that part of the furnace where they are to be inserted, slit for four inches at each extremity, and the ends turned up, are built in each alternate course round the fire-room and chamber; by which means the expansion of the furnace is attempted to be checked, and its retraction secured.

The usual method of bricklayers building in pieces of small hoop-iron between the courses of brick is a ridiculous absurdity. Nor should a chemist allow them to plaster over his furnace, or surround their edges with cloth, or sheets of lead. If there be fear of the edges getting chipped by pails or other vessels, let them be surrounded with an iron hoop, or if this should be prejudicial to the materials which may be at times dragged over them, then the edges may be made of a wooden curb, fastened together with tree-nails.

FURNACES FOR CHEMICAL OPERATIONS IN GENERAL.

The Stove-Holes.

The stove-holes, as they are usually called, are the most useful of all furnaces; and, although this is so generally known that they are not only to be found in all druggist's laboratories, but also in all well-furnished kitchens, where they are used for the nicer operations of household economy, yet they have of late years been omitted to be described in any of our elementary treatises of chemistry, which have, instead thereof, descriptions of Cramer's athanor, or tower, furnace and other over curious contrivances, never used in English laboratories.

Stove-holes are generally constructed in pairs, it being frequently necessary to mix together two liquids at different temperatures, each of which, of course, requires a separate fire to prepare it.

Fig. 1, which is drawn on the scale of half an inch to a foot, represents the most approved construction: first, a space, *a*, *b*, *c*, on the floor, is marked out under a chimney, or hood, that may carry off the vapours. This space is to be thirty-seven inches and a half wide, and twenty-one inches from front to back. This space is to be surrounded by a wall of bricks laid on the flat sides, and with a similar wall in the middle of the open space. These walls are to be carried up to the height of two feet, by which means, two hollow prismatic ash-pits of twelve inches square will be left, with a partition four inches and a half in breadth between them, and having the outward boundary walls of the same thickness.

By the ash-pits being thus tall, a good draught of air will be made, if at the bottom in the front of each ash-pit a hole, *d*, five inches by four, be left to admit the air, the ingress of which is to be regulated either by an iron door, a slider, or by brick wedges, which, being pulled out more or less, will allow more or less air to pass.

On the top of each of these ash-pits is to be laid a grate, composed of iron bars, seven-eighths of an inch square, set on their edges an inch apart, and connected by two end bars, which lie in two tiles, or pins, forming sufficient ledges in the walls of the ash-pits. The walls are then to be raised twelve inches above the grate, leaving in the front of each fire-place a fire-room hole, *e*, four inches high and five wide, whose lower edge is about one inch above the grate, which holes are to be closed by iron doors.

The tops of the fire-places are entirely open, and the walls are continued all round of an even height, except that the outer side-wall, *f*, of each fire-place, is to be carried up only six inches from the grate, and the remainder left open; to which open place, loose pieces of brick are to be fitted, to close it when it is not wanted to be open.

It is most usual to have all the walls half a brick, or 4 inches .5 thick, as already described; but as these thick walls occasion a waste of fuel and time in heating such a mass of brick-work, Weigel recommends the walls to be only three inches thick at the farthest. In this case, the walls are built of bricks set on edge, and they must be held together with iron braces, fastened round the furnace with nuts and screws, and then plastered over about half an inch thick of Windsor clay, or enclosed in a cast iron case made for this purpose.

As distillation by the retort is a frequent operation in chemistry, one of these stove-holes is usually fitted for that purpose, by having a cast-iron pot, about six inches over, and as many deep, set sloping in the open space left in the outer wall, and supported in this position by an iron stand adapted for the purpose, and set on the grate. The space between the mouth of the pot and the walls of the furnace is then filled up with pieces of brick and clay. The fitting in of this cast-iron pot, which is intended to contain the glass retort and sand, does not prevent the furnace from being used in many other operations.

When it is intended to use a high degree of heat, the top of the retort must be covered with sand: and for this purpose, the mouth of the pot must be covered with two plates of sheet-iron, having notches cut in them to let the neck of the retort pass; and smaller notches above these, even with the upper part of the mouth of the pot, to form a circular hole through which sand may be poured to fill up the pot entirely. These iron plates are kept in their proper places by pins inserted in holes drilled in the edge of the pot, or of the iron-bands of the furnace. This filling up the sloping iron-pot with sand has, however, the inconvenience of preventing the bottom of the retort from being seen.

The other stove-hole will then serve for melting any thing in crucibles, or pipkins, and may have, as well as the other, its cavity contracted by loose bricks put into it. The short wall on the outer side is convenient when only a small fire is required; or when it is intended to distil in a coated glass or earthen retort, placed on a piece of brick in the middle of the fire; and if an iron plate is placed over either stove-hole to form a sand heat, a small hole may, by taking out one of the loose bricks, be left for a vent, if there be no other.

It may easily be conceived that boilers, shallow pans of copper, or even a small copper or tin plate still, may be placed over either of the holes, and, in short, that every operation may be performed with them, except such as require an excessive heat.

charcoal or coke is usually burned in these stove-holes, they have in ge- no vents or flues, but if it is intended to burn raw pit coal in them, or any smoking fuel, vents, *g*, must be made in the back wall about eight inches and three high, to carry off the smoke: these vents should be about three s below the top of the furnace, and open into the flue of a chimney, need not be of any great height.

foreign laboratories, some of the stove-holes are made with the fire-room once and a half to twice as deep as it is wide. These deep stove-holes, have a couple of iron bars placed across them from front to back, about vay from the grate to the upper edge; which bars are intended to support rthen retort, an iron-pot for a sand-bath, or any other vessel. These are urnaces which are called *reverberatory furnaces* by the French authors and translators, and *distillatory furnaces* by the Germans. As the chemists in countries universally use charcoal for their fuel, their stove-holes have no in the back wall opening into a flue; but in distillations by the naked fire, stopping up the side opening with clay, the French cover them with a e of baked earth, the upper part of which is drawn out into a short chim- a few inches in length; and the Germans are content with covering them a flat slab of fire-stone or a large tile, leaving small openings at the cor- for the sake of the draught.

The Furnace for the Sand-pot and Sand-bath.

The furnace for the sand-pot and sand-bath is a very import- and useful furnace; but in the usual way of building such naces, they are not only defective and faulty, in all the ge- al points before mentioned, but in others also, respecting proper proportion of this particular kind. This furnace is nded to serve for the sublimation of salts, and distillations all kinds performed in retorts, as also evaporations from s or wedgewood dishes. It heats at the same time, when antageously constructed, a sand-pot and sand-bath. In the d-pot any operation may be performed in one retort, where degree of heat required is from that of boiling oil to the degree of glowing heat, or what is called red-hot. In ge- al, the retort is sunk in the sand, and even covered with it; sometimes only as much sand is put in the pot as will keep retort steady, and this is called a *capella vacua*.

n the sand-bath may be performed several distillations, ere different degrees of heat are required, from that of boil- spirits of wine to that of boiling oil, as the bath may be le large enough to contain five retorts or other vessels of the e magnitude, which, by being placed nearer or more remote n the sand-pot, or fixed higher or lower in the sand, may er the several degrees of heat each shall require.

he first step towards making this furnace is to procure a proper sand-pot, two large plates for forming the sand-bath. The size of the sand-pot must etermined by the magnitude of the retorts, or bodies, intended to be used it must be so proportioned as to hold the retort, and to allow about two es space for the sand to surround it on every side. The best form of sand- is that of a cylinder with a concave bottom, which ought to be made dou- he thickness of the sides. The common pots are generally made with thin ms, which subject them to be very soon worn out, if exposed to a strong

The plates for the bath should also be of cast-iron, and must be proportioned to the size and number of retorts, or other vessels, proposed to be worked. They must be long enough to allow at least two inches space betwixt every retort, and two inches and a half betwixt them and the sides of the bath, with the addition of two inches for its bearing on the sides of the hollow it is to cover: the same proportion must be observed for the breadth. They may be as thin as it can be well cast, but care must be taken not to break them in the moving or fixing, which may otherwise very easily happen.

A flat ring of iron, of about three inches breadth and of a proper magnitude to receive the edge of the pot into a proper groove or rabbit made in its own inner edge, should also be provided.

Two iron doors, with their proper frames and bars for the ash-hole and fire-place, and also an iron frame or slab and bars for the hole for feeding the fire, with other bars and plates for the hollow parts of the furnace, must likewise be prepared, according to the general directions above given.

When the iron work is thus prepared, the particular manner of constructing the furnace must be as follows:—

The dimensions of the furnace must be first settled by this method. It will also serve for obtaining those of any other kind of furnace designed to be built, where the object to be heated is of a constant or fixed nature.

The diameter of the sand-pot intended to be used being first taken, six inches must be added to it, for the cavity round the pot, and also the length of two bricks, to allow for the thickness of the sides of the furnace. These being put together, give the diameter of the whole furnace. To find the due height, the height of the pot must be first taken; to which must be added eight inches for the distance betwixt the pot and the surface of the fire when at the highest; six inches for the depth of the fire-place, and eight inches for the distance of the bars from the ground of the ash-hole; with the height of a brick for a course that must be carried over the edge of the pot, which being all put together, give the height of the whole furnace from the foundation.

A round or square cavity must then be made in the ground, on the place where the furnace is to be erected. This must be large enough to admit the laying the foundation of the furnace in it, and about eight inches deep, that the bars of the fire-place may lie on a level with the ground, the ash-hole being below it.

The reason for making this part of the furnace below the ground is to prevent the other parts from rising too high. With respect to the sand-pot, this is a great inconvenience to the operator when he has occasion to put a charged retort into the pot; for in doing this he greatly loses his command of it, if the pot be placed high. But still greater will the inconvenience be with regard to the sand-bath, which being of course considerably higher than the sand-pot, requires in this case that the operator should have something to stand upon, in order to manage the full retorts set into it;—an expedient always to be avoided.

The ground plan or foundation of the furnace must be laid in this hole, of dimensions suitable to the diameter, as computed by the rules above given, and carried up of solid brick-work, of a cylindrical or square form. But an area, *a*, must be left for the ash-hole, which must be proportioned by laying the bars fixed in their proper situation, by means of the cross-bearing bars in the ground, in the centre of the cylinder, and drawing two lines, begun at the farthest cross bar, and continued parallel to the two outermost bars, at the distance of a quarter of an inch from them, to the front of the cylinder. The space so described must be left hollow, and the ash-pit door set in the front. This part of the work may be done with common bricks and coal-ash mortar; but they must be laid solid, that the whole mass may not shrink when the mortar shall be subjected to a great heat. The cylinder of brick-work being thus raised about eight inches high, the bars of the fire-place must be laid over the innermost part of the vacuity left for the ash-hole; and the stoking-door, with its frame, *b*, must be also placed in front of the bars; but they will not, in this manner of construction, coincide with the interior surface or front wall of the furnace. The brick-work must then be again carried up six inches, in the same manner as before; only it must be made to take proper hold both of

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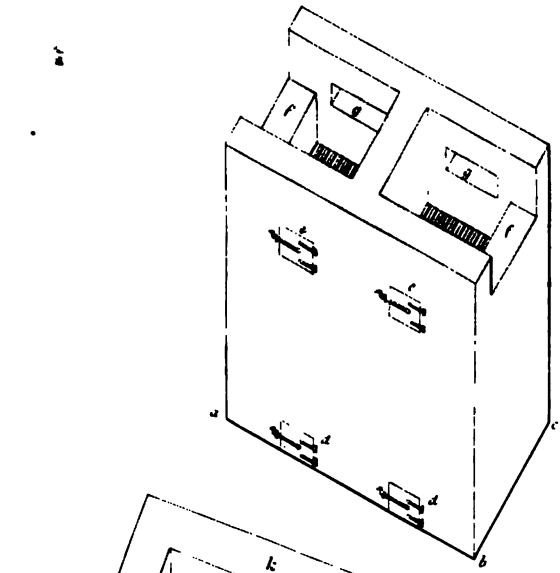


Fig. 1.

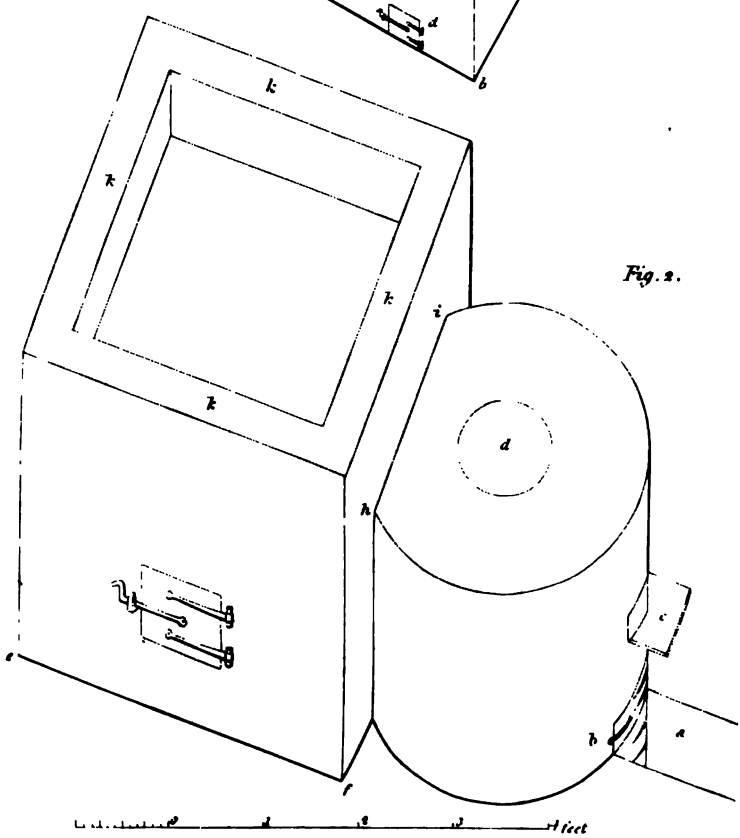


Fig. 2.

J. Drayton Sc

the cross-bars of the fire-place and frame of the door. But the courses next the fire must be of Windsor brick, and laid with Windsor loam, or Stourbridge clay. If the heat be intended to be very violent, the joints next the fire should be pointed with the fire-lute hereafter mentioned.

When the fabric is raised to this height an iron plate of sufficient strength, or two broad bars, should be laid over the void part or opening, leading to the door and ash-hole, that the brick-work may be carried entirely round above. The cylinder must then be continued as before, only the cavity must then be made sloping from the upper part of the area designed for the fire-place, and enlarged gradually, so that in raising the furnace eight inches higher, the diameter of the cavity shall be six inches more than the diameter of the sand-pot. These six inches are to allow for the three inches distance betwixt the pot and the sides of the furnace, that will here begin to be parallel. The slab for forming the hole, *c*, for feeding the fire, as before described, should be fixed in the last course of bricks which make this slope. The most convenient situation for it is the front of the furnace, directly over the opening for the door and ash-hole.

From this height a cylinder must be carried up parallel to the sides of the sand-pot, at three inches distance, till within something less than the third of the top of the sand-pot, supposing the bottom to be on a level with the first of this cylinder. The hollow then must slope gradually inwards till it be no wider than just to suffer the sand-pot to be let down into it.

In the brick-work of this upper slope must be left a cavity for conveying the smoke and flame under the plate of the sand-bath. It must be in the centre of that part where the fabric of the sand-bath joins the furnace, and should be four inches and a half, or five inches in length, and about two inches in height.

The whole of this part of the furnace may be of common brick, but the mortar should be of Windsor loam. On the top of the brick-work raised to this state, must be laid the iron ring or rim before-mentioned, designed to hold the sand-pot.

It should be laid in with fire-lute, and well pointed with the same at the joint it makes with the bricks within the hollow of the furnace. A proper plate should also be laid over the cavity left for carrying the smoke and flame under the sand-bath.

When these parts of the furnace are so dried as to hold well together, the pot, *d*, should be let down into the ring, where it must hang by its own rim or turned edge, and another course of bricks then be raised in a continued line with the sides of the sand-pot: that part of them which touches the pot being laid in fire-lute, and the other parts in coal-ash mortar. In this course a slope must be made on the side opposite to the sand-bath or front, which ever shall appear most convenient, for the neck of the retorts to bend sufficiently downwards when placed in the pot. The whole of the furnace which relates to the sand-pot being so completed, the sand-bath must be thus added.

A ground plan or foundation, *e f*, must first be laid, which needs not, in this case, be sunk below the level of the flooring of the place: it must be proportioned according to the size of the plate intended to be used. The length must be that of the plate, with the addition of the breadth of two bricks; the breadth must be that of the plate, and the length of two bricks. It must be formed by building as it were four walls that mark out this proportion; the area within them is to be well paved with square tiles and left hollow. The walls may be built with common bricks and common mortar: only great care should be taken that the bricks may rest every where on each other, so that there may be no settling when the work shall be dry: and that a large iron door and frame be firmly fixed about the middle of the front wall. In adjusting the site of the area marked out for this foundation, about three inches length of the side of the furnace round the sand-pot must be taken into the end of the area next it. This projection of the one part of the furnace into the other, *h i*, is necessary, in order to bring the end of the plate close to the flue; that is, to convey the flame and smoke into the cavity under it, without being obliged to lengthen the passage, which otherwise must be the case if the whole square

heated, and the separation wall is of great use in supporting the bottoms of the boilers. By dividing the fire-room into three, four, or more spaces, separated from each other by walls, and each space containing a fire-room, the advantages of a still more equable diffusion of the heated air, and of a more effectual support to the boiler, would be obtained.

Fig. 4, represents a vertical section of a steam-boiler and furnace, with two fire-rooms; drawn on a scale of one-eighth of an inch to a foot.

Fig. 5, represents a horizontal section of the same; *a*, a wall which extends from the bottom of the ash-hole to the bottom of the boiler, and to the top of the flues, or space for containing the heated air, round the sides of the boiler. This wall cuts off all communication between the two furnaces and fire-rooms, or spaces for containing the heated air, and gives support to the bottom and sides of the boiler; *b*, shows the grates or bars on which the fuel is burnt; *c*, a dead plate which separates the ash-hole and fire-room, and prevents the ascent of the atmospheric air from the former to the latter; *d*, the ash-room door; *e*, the fire-room door; *f*, pillars on which the boiler rests, with a bearance of nine inches, more or less according to the size of the boiler, within the extreme periphery of the bottom; *g*, the boiler; *h*, the spaces round the sides of the boiler, into which the heated air ascends from the fire-room, through the openings between the pillars; *i*, spaces through which the burned air, after acting on the boiler, may be conveyed through flues, *k*, to one chimney, *l*, placed in any convenient situation, as shown in the plan, Fig. 5. In these flues, dampers may be introduced, by which the penetration of the air through the two furnaces may be effectually equalized, and, by inserting another damper in the chimney, both furnaces may be completely regulated.

As instances of the steady, rapid, and intense action of furnaces on this construction, a round boiler of thirteen feet diameter, without any flue through it, was not only brought to boil, but furnished steam of sufficient power to work a machine of twenty-horse power, put up by Messrs. Boulton and Watt, in eight minutes from the time it was filled sufficiently high with water, the fire being put in when the bottom was covered; and which engine was at work within the space of seventeen minutes from the time of its being filled with water.

A similar boiler, placed on the usual construction, required an hour and a quarter to raise the steam to the same degree of elasticity, as the boiler of this construction produced within eight minutes after it was filled above the flues, the fire being put in when the bottom was covered; and as it was a competition of skill, every possible exertion was used on both sides.

This plan has been applied to the boiler of an engine for drawing coals, at Killingworth colliery, in Northumberland, which, on the usual plan, was inadequate to raise steam to do the work required; namely, to draw forty score of twenty peck corfs of coals, in fourteen hours, from a pit 120 fathoms deep, although the engine, built by Messrs. Fenton, Murray, and Co., was well constructed, and kept in perfect order. The boiler is a round one, of thirteen feet diameter, without a flue

Pl. 2.

Fig 3

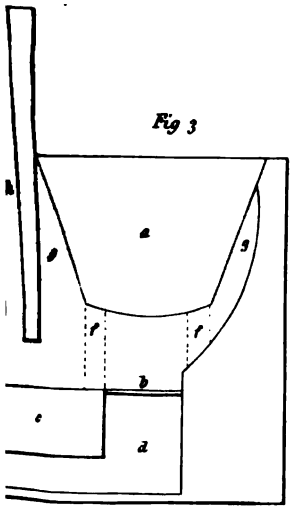


Fig 5

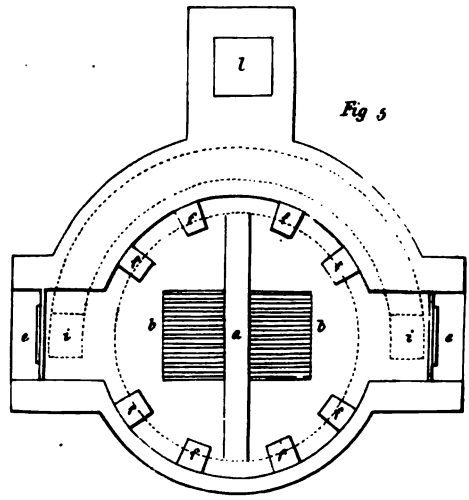


Fig. 4.

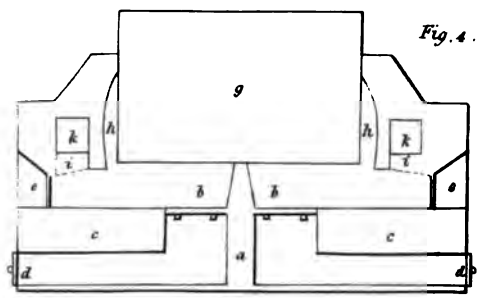
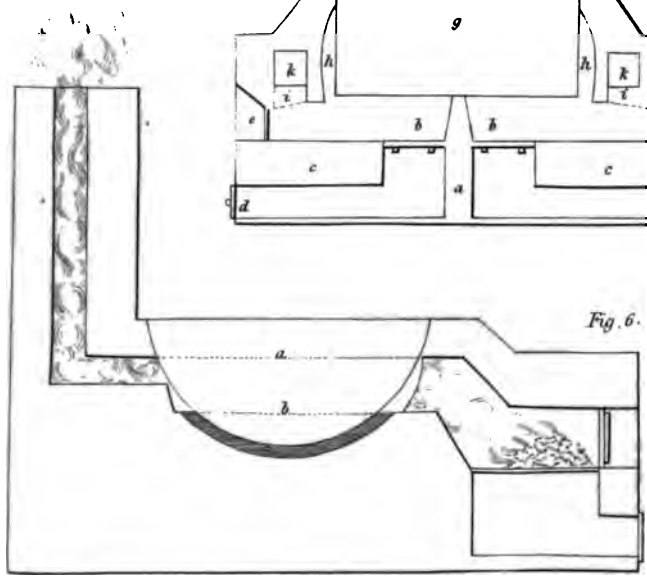
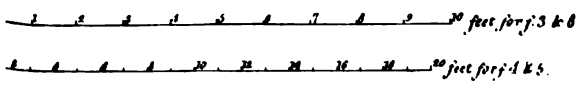


Fig. 6.





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through it, and the cylinder of the engine thirty inches diameter. Since Mr. Losh's plan has been adopted, the engine performs the work with perfect ease, although nothing but the smallest refuse coal is employed, and that only in the proportion of one-half of what was used before the improvement, without producing the desired effect. The engine will now work at its full power for nearly an hour after a fresh supply of fuel; whereas, on the former plan it was requisite to give a fresh supply every ten minutes, or oftener. And although the effect of the heated air is so powerful, yet the fire itself is so moderate, and the combustion of fuel so gradual and perfect, that no scars are formed; and in consequence it is only found necessary to clean the grates once in two days, although the coals are of that quality which have a great tendency to vitrify at a high degree of heat.

The only instructions necessary relative to firing, or adding fresh supplies of fuel to boilers on this plan, are, to throw in much less at once than is usually done, to keep the bars well covered, but the fuel much thinner upon them, and the fires much brighter than in common furnaces; to wait after adding coals to one furnace, till it has become bright, before a fresh supply is given to the other; so that when one fire is at its highest degree of heat, the other is at its lowest, and thus the boiler may be kept continually at nearly an equal temperature;—the advantages are evident.

Salt Boilers.

It is a fact well known to those who are interested in chemical works, that boilers of cast iron, with their bottom fully exposed to the fire, cannot be employed with safety either in lixiviating ponderous substances, or in concentrating the solution of any salt which crystallizes at the surface of the liquid by evaporation; because in the former case the mass of the materials resting on the bottom of the vessel; and in the latter, the crystallized salt which falls down, is apt to fix on the bottom of the boiler, and ultimately to rend it.

Although boilers made of malleable iron are not subject to the same inconvenience from these causes, yet in a number of cases they cannot be employed with safety. In the solution of a salt, for instance, which contains the smallest predominance of any of the mineral acids, these acting on the joints and rivets, in a short time corrode, and render them unserviceable, which frequently causes not only loss but disappointment.

The boilers which are found most advantageous to use for the evaporation of dense liquids, where the salt crystallizes at the surface by evaporation, such as muriate of soda or sul-

as a syphon. The adopter or condensing pipe, with its casing, being supported at a proper height, on a moveable frame of wood work, a short pipe with a cock is soldered to the lower end of the casing, another short pipe to the upper part of the upper end of the casing, and a longer pipe with a cock to the lower part of the same upper end of the casing; this last pipe must be of such length that its lower end may be below the level of the lower end of the short pipe attached to the lower extremity of the casing.

Now to use this moveable condensing apparatus, a vessel of water being placed under the pipe attached to the lower end of the casing, and the cocks of both the pipes closed, water is to be poured into the casing by the short pipe at its upper part, until it is completely filled, when this pipe is closed with a cork. The cocks being then opened, the casing with its two pipes will act as a syphon or crane, and the water in the vessel will rise through the casing and pass off through the longer pipe, either into an empty pail placed there, or run to waste on the floor. The current is to be regulated by opening the cock of the longer pipe more or less.

The proper receiver to be generally used with these adopters is a matrass, having an *s* pipe in the middle of its height; so that if any oil come over with the distilled liquor it may be retained in the receiver, while the aqueous fluid is allowed to pass away by the pipe into bottles placed to receive it. The oil, if lighter than water, will float upon it; and, if heavier, sink to the bottom of the receiver.

Fig. 7, is the geometric representation of a still with a moor's head fitted with a syphon cooler, and close Italian receiver, drawn on a scale of half an inch to a foot. *a*, is the ash-room door; *b*, the place of the grate; *c*, the stoking-door; *d*, the feeding-hole for the fire, with its slab; *e*, the vent at the back of the furnace; *f*, the body of the still, which being thirty inches wide and twenty inches high, will hold, when half full, twenty-seven gallons; and when three quarters filled, forty-one gallons: *g*, a short pipe by which the still may be filled, or the liquor in it drawn off by a crane, without taking off the head; *h*, the neck of the head; *i*, the moor's head, with its nose; *k*, the adopter to lengthen the nose, which, for the sake of room, is represented only half the proper length; *l*, the cooling pipe, through which the water runs up, surrounding the adopter, and cools the vapour in it; *m*, the shorter pipe of the syphon, immersed in a broad shallow tub of water; *n*, the longer pipe of the syphon; *o*, the cock to the shorter pipe, placed at the very extremity; *p*, the cock of the longer pipe, which may be placed any where below the level of *o*; *q*, the close Italian receiver, retaining the essential oils, when the still is used for distilling those articles, and allowing the water to pass off by the spout, *r*.

Should a person prefer the use of a tub with the adopter sunk in the water, the following is the best construction for general purposes, as the straight adopter is the only one that can be cleaned.

Fig. 8, represents this tub, which is generally made of copper, or zinc plates soldered together. The adopter itself is made of three pipes, *ab*, *cd*, *ef*, each

Fig 7.

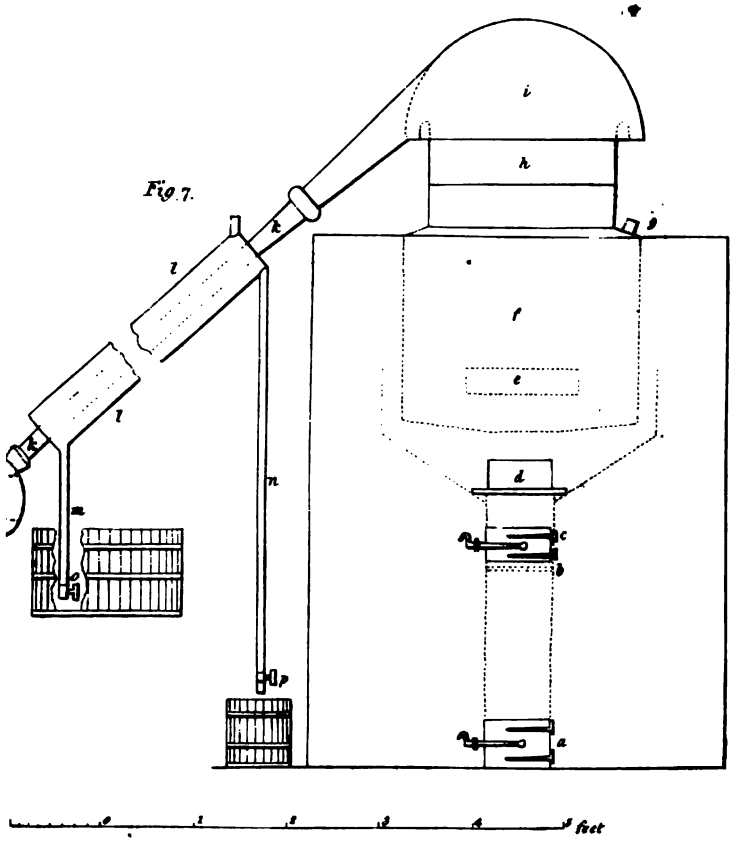
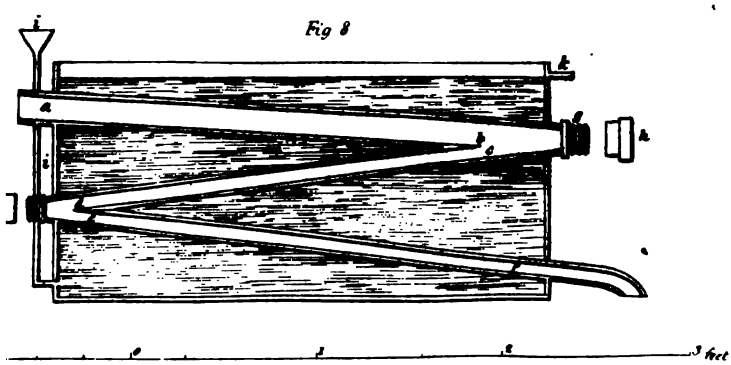
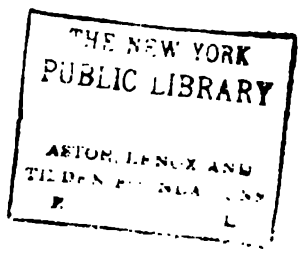


Fig 8

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about a yard long, cut off sloping at each end, and soldered together, so as to form one continuous pipe. The ends of the pipes, which are also soldered to the tub, have a hollow ring, with an external male screw, *g*, *i*, soldered also to them, and on each of these is screwed a solid cap, *h*, *m*, having a leather ring placed between them, to secure the joint.

The tub containing these three pipes, or more, if it be thought necessary, need not be deeper, from front to back, than about three times the breadth of the widest pipe, as the water can be continually changed, when it grows warm by a gutter being conducted from the cock of the laboratory cistern to the funnel, *i*; and the warmed water will pass off by the spout, *k*. A cock soldered at the lower part of this tub is necessary to empty it occasionally.

The caps, *h* and *m*, being unscrewed, the pipes are easily cleaned by means of an iron rod, wrapped round with some tow.

The Water-Bath, or Balneum Maris.

A vessel of hot water is often used as a medium for the communication of heat: and is then called a water-bath.

When a water-bath is used for evaporation only, then the boiler need not be deeper than two-thirds of its width; and the water-bath may be a hemispherical vessel, of rather less diameter than the boiler, to allow room for a short pipe, by which water is poured into the boiler, and another longer pipe, by which the steam is allowed to escape, and is directed into the draught of a hood or chimney, or into the ash-hole of the furnace. The furnace for heating the boiler is precisely similar to that for the still.

For distilling by the water-bath, a still of the ordinary form is surrounded by a boiler about four inches wider and deeper than the body of the still, with the same pipes as in the former case.

Some use a long narrow cylinder, which they insert, when wanted, in the mouth of the common still, but it is far better to have a peculiar still for this purpose.

For evaporation of liquids, another mode of heating them has been adopted in a few instances; as for boiling syrup, by the circulation of heated oil, forced by a pump through pipes immersed in the vessel containing the syrup. And the circulation of heated water has been used for hatching eggs on the large scale of a manufactory, and to heat green-houses.

The Steam-Bath, or Balneum Vaporis.

The use of a steam-bath, or balneum vaporis, of the old chemists is, at present, in great favour with many chemical artists, in preparing articles on the large scale; but the apparatus necessary for the vapour-bath being rather complex, and the water-bath affording the same facility of tempering the heat, and restraining it within a certain temperature, it is seldom employed in laboratories for general purposes.

The original use of the steam-bath, as we learn from Gesner's Evonymus, was to serve as an elegant substitute for the heat of a dunghill, still used by gardeners. The steam was

conveyed by a pipe into a square wooden chest, filled with chaff, or cut straw, in which the vessels containing the materials were placed; the part of the steam-pipe that traversed the chest from end to end, was pierced with numerous holes, through which the steam made its way, and condensing on the chaff, heated it gently. The condensed water was allowed to run off at one corner of the chest.

Lemeri's vapour-bath was a flat-bottomed copper still, which fitted into the mouth of a boiler, with three pipes round it to allow the passage of the steam into the atmosphere.

At present chemists and housewives have, for common purposes, returned to the old form of the steam, or vapour bath. The water is boiled in a copper, or even tin-ware, kettle, set in a furnace. This kettle has a double cover that fits close, and on one side of it is a pipe, directed upwards. A square chest of thin plate iron, japanned, or even tin-ware, is placed in a convenient situation near the boiler, and with its bottom rather above the level of the mouth of the kettle. A pipe of the proper length forms the communication between this steam-chest and the kettle; this pipe enters into the pipe of the kettle, and is made to fit very close. The bottom of the steam-chest is set so as to slant a little, that the condensed steam may run down these pipes into the kettle again. The top of the steam-chest is pierced with several holes of different sizes, into which are fitted tin-ware vessels for the different operations intended to be performed. A pipe at the farther end of the steam-chest allows a passage to the surplus steam that is produced, and directs it either into the draught of the chimney, or of the furnace itself.

Fig. 9, represents a small laboratory steam-boiler, for steam of a moderate force, with its several appendages; *a*, is the ash-pit, with its door; *b*, the fire-room; *c*, the feeding-hole, with its slab, to be stopped with small coal; *d*, the stoking-hole of the fire-place; *e*, the lower gauge-pipe and cock, to know whether there is a deficiency of water, as in that case, steam will issue when the cock is opened; but if there is sufficient water it will come out of the cock: *f*, the upper gauge-pipe and cock, to ascertain whether there be too much water in the boiler, as in that case, water will issue through the cock when opened; but if there is not a surplus of water, steam will pass through the cock; *h*, the feeding-pipe, connected with the cistern of water; *i*, the cock which cuts off the communication between the cistern and the steam-boiler; *k*, a safety-pipe, bent at the top, so that if at any time the water should be forced up, it may be thrown into the cistern. The height of the upper part of the bend of this pipe above the level of the water in the cistern, determines the utmost strength of the pressure of the steam; *l*, the steam-pipe, by which the steam is conveyed where it is to be applied: this pipe is to be shut by a steam-cock, which ought to be so constructed that it cannot be at any time entirely shut, but that there may always remain a small passage for the steam.

This is all the apparatus necessary for the occasional application of steam to chemical works, when the temperature that is to be produced by the difference of the level between the up-

per surface of the water in the laboratory-cistern and that in the boiler is sufficient for the purpose. But when what is called high pressure steam is required, a more complicated apparatus is necessary, and the boiler must have an engine attached to it, as in that case the water cannot be introduced by a common feed-pipe by its own pressure, but must be forced into the boiler by a forcing pump, and is therefore more the object of engineers than chemists.

The steam-boiler, with all its hollow appendages, ought to be made very strong, so as to resist the internal pressure made against its sides by the expansive force of the steam contained within it, and also the external pressure of the atmosphere in case a vacuum should be formed within it by a sudden condensation of the steam.

For a laboratory steam-boiler, the upright cylindrical form is as good as any; but for engines, or heating rooms, a wagon-formed boiler is perhaps the most usual. It is generally made of iron, rather wide and shallow than the contrary, and the whole of the lower part, as high as the water reaches, is exposed to the fire. The greatest effect in producing steam is obtained when the horizontal area is about twenty-one square feet. The water in it is to be kept so as to half fill it; and for that purpose the gauge-cocks must be frequently opened, to see that the lower cock lets out water, and the upper cock steam. If both let out water, it is too full, and the upper gauge-cock must be left open till the water no longer runs out. If both gauge-cocks emit steam, the boiler wants replenishing with water, which in these small boilers, is effected by turning the cock of the feed-pipe, and leaving open the upper gague-cock to show when the necessary quantity has entered. In the large boilers of steam engines and the like, mechanical contrivances are adopted to cause the cock of the feeding-pipe, or a valve at its exit from the cistern, to open whenever it is necessary, by means of a float on the water balanced by a counter weight as hereafter described in treating of heating rooms. An attentive chemical operator will soon acquire a knowledge of the power of his furnace, and give a shrewd guess at the intervals which may be allowed between the feedings.

The safety-pipe should enter as deep into the boiler as that its extremity may be a little below the level of the lower gauge-pipe, or at the utmost half way into the water when the boiler is properly filled. Hence, should the operator omit to replenish his boiler with water, then as soon as the level of the water falls below the lower extremity of the feeding-pipe, the steam will rush up it, and appear at the upper end of the safety-pipe. This pipe may also be formed into the shape of a boatswain's-whistle, or organ-pipe, and then the steam passing

force, and consequently the temperature of the steam. The difference in time arose, he supposes, from the condensed water having, in the former case, been occasionally taken away by turning a stop cock in the most depending part of the jacket; for this being omitted is found to retard the heating of the liquid.

Mr. Taylor informs us, that when a coil of 280 feet of leaden pipe, one inch and five-eighths in diameter on the outside, was laid down in a copper boiler of about eight feet diameter, in which eight barrels of wort were usually boiled, so as to cover and rest on the bottom, and steam of the force of forty pounds to the inch, having, of course, the temperature of about 280 degrees Fahrenheit, was admitted into this coil, ten barrels of wort were brought to boil strongly in fifteen minutes, and were evaporated to six barrels in an hour's time.

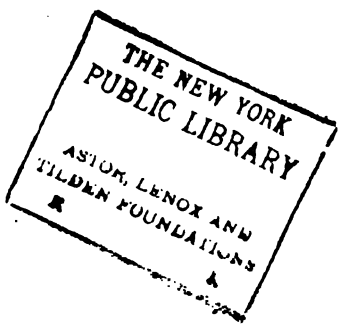
That no part of the heat of the steam may be wasted, all the exposed parts of the boiler, the steam pipes, the cast iron jackets in which the boilers are contained, and the conduit pipes for the condensed water, ought to be closely enveloped with bands of straw, and plastered over with mortar, or enclosed in double walls.

The great advantage of a steam apparatus is the quickness with which a vessel filled with water is brought to boil, by merely turning on the steam into its jacket; to which may be added the avoidance of the dust and filth of the fire. These advantages are counterbalanced by the original expense of erecting the apparatus, and the great consumption of fuel, if all the steam produced is not brought into use. Hence this method of heating is only practicable with economy in dye-houses, calico-printing works, and similar establishments on a large scale.

The main steam-pipe in ordinary steam apparatus, ought to have a cock at its farther end, which, like that next the boiler, should not shut quite close, but always allow the escape of a small quantity of steam. This cock is to be opened when the steam is first let into the main, to allow the air, which the steam drives before it, to escape, and when the steam appears the cock is shut. In like manner each of the cast iron jackets must have a similar blow cock to let out the air when the steam is first let into them; and to let it in again when the steam is shut off, as well as a cock or pipe to carry off the water of condensation.

As the heat that escapes from the sand-pot is brought into use by the construction of a sand-bath behind it, so chemists have from the earliest times made use of the heat that escapes from the common boiler or still.

In many chemical works, a plan is adopted of heating water, or other liquor, in a boiler placed on a mass of masonry, or arches, somewhat similar to the manner of the sand-heat, and connected with the boiler by a pipe with a cock; and when the liquor in the still, or first boiler, is done with and removed, the cock is turned, and that in the second boiler supplies its place.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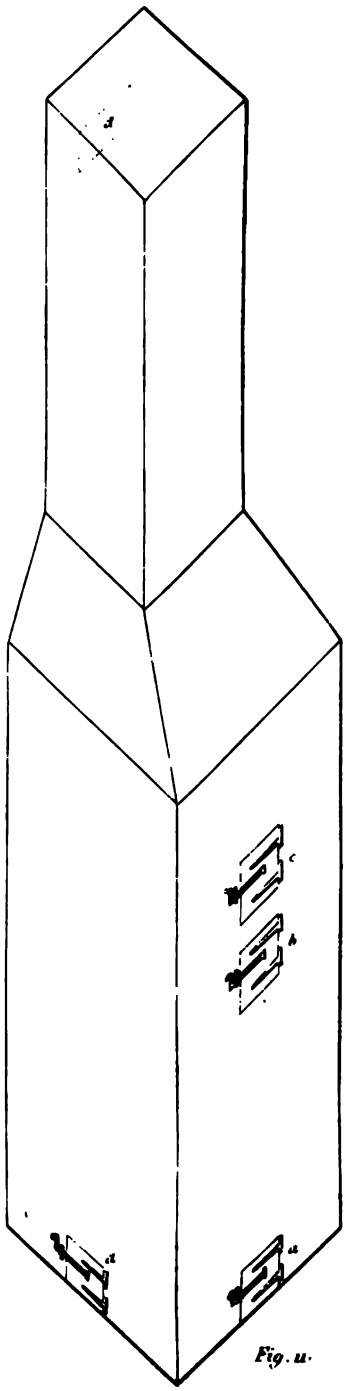
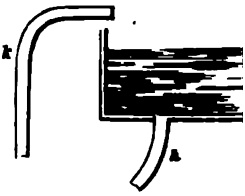


Fig. u.

Fig. 9.



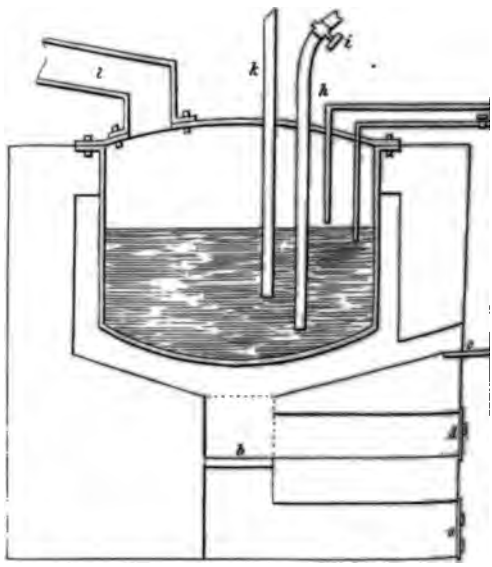
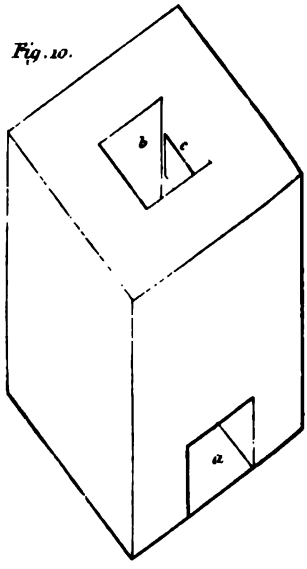


Fig. 10.



great brewers have even endeavoured to turn to use the
at escapes through the covers of their boilers, and have sur-
:d the cover with an upright ledge, so as to form a kind
ern, or, as they call it, a dome and a baque, vulgarly
l *back;* but the word is really a French term for a large
i its diminutive, baquet, is for a small tub, or pail. When
iler is emptied, the water thus heated over the other is
and thus the time of boiling is abridged.

foult, in 1815, took out a patent for employing not only water and sand
s to transmit heat, but also linseed oil, quicksilver, oil of vitriol, and
quids, or easily fusible substances. He connected the bath itself with
ing apparatus, and thus either collected the condensed vapour for use,
:d it to return into the bath.
ing linseed oil as a bath, he collects the portion that is evaporated, and
s the same oil repeatedly for a bath until it is sufficiently boiled to be-
ainter's boiled oil.

The Melting, or Founder's Furnace.

urnace is required in laboratories for melting metals, with-
e labour of blowing, and is usually called the melting, or
er's furnace. It has this inconvenience attending its use,
: requires nearly an hour before it acquires its full power;
ıe heat is more steady than that of the blast furnaces.

construction is remarkably simple.

10, represents this furnace, drawn on a scale of half an inch to a foot.
the operator may be complete master over his crucibles, the grate is
nearly on a level with the ground, the ash-room, *a*, being only about six,
ost nine inches above it, open on both sides, but close in front. The
ce is generally a rectangular prism, the internal cavity, *b*, having its sides
inches, and its depth twenty-four. Two rows of bricks are merely laid
to each other, at nine inches distance, to form the front and back of
-pit. Upon these are placed two strong iron bars to support the fire-
ıd another course of bricks laid, leaving space for the reception and ex-
of the bars.
broad iron bars are then laid a little above the fire-bars, to support the
the fire-place, which is continued up of bricks capable of bearing the
n the back of the furnace is left a vent, *c*, usually four inches high and
vide, which, being covered over, communicates with a chimney into
no other furnace opens.
cover of these furnaces is usually made of an iron case, lined next the
h clay and charcoal, and having a handle.
grate is composed of four or five loose iron bars, an inch square, which
sometimes closer, sometimes more open, by taking one out, or putting
as is judged proper to regulate the draught.
ıe entrances for the air being on the sides, the radiant heat from the
of the fire is prevented from incommoding the operator as he stands in
ıt of it, and the fire-bars being loose, when they are burned, the furnace
equired to be pulled down to replace them.
coal is the best fuel for this furnace; if coke be used, it forms clinkers
ılent heat, which clogs up the fire bars, and requires them to be conti-
:leared by a fire-hook, and those adhering to the sides, occasionally re-
by a four-foot poker, terminating in a three-inch chisel edge.
evix proposed to make this furnace three inches wider at bottom than

Boerhaave's Reverberatory.

A chemical laboratory must also necessarily have a particular furnace for distilling the mineral acids, as those of sea-salt, nitre, alum, vitriol, or any other distillations which require a stronger heat than can be given in the sand-pit.

After several trials, Boerhaave has recommended the following as fittest for the purpose, which is represented in Fig. 13, on a scale of half an inch to a foot.

Upon the pavement of the laboratory under the chimney, build up a parallelopiped, thirty inches broad in front, *a b*; and forty inches long from *a* to *c*. Let the cavity be twelve inches wide in front, and twenty-two inches long, which gives one brick, or nine inches, for the thickness of the wall. Let the parallelopiped be raised eleven inches high; make a door-way, *d*, in the middle of the front, rising eleven inches from the ground, and four inches wide, leaving an indenture in the front of the furnace to receive an iron-door, and let in close occasionally.

This part of the apparatus regards the ash-room of the furnace and entrance for air. Instead of a grate in one piece, here use prismatic iron bars, an inch wide and fourteen inches long, placing them an inch asunder, parallel with the breadth of the ash-room, and support them by two strong bars. Then build up the walls on all the sides fifteen inches in height.

In the front wall, immediately over the ash-hole, make a door-way to the fire-place, *e*, seven inches wide, and nine inches high; and let this door-way be exactly fitted with an iron door, the lower line of which is three inches above the upper line of the ash-hole.

In the middle of one of the long sides or front there must be an arched opening, *f*, with its lower limit rising ten inches above the grate, and being twenty inches long and twelve inches high.

This opening is for the distilling vessels to be put in and taken out at. On the internal side, opposite to this opening, at the height of nine inches above the grate, a ledge of an inch and a half must be left in the back wall, to support the vessels employed in the distillation; and in the middle of the upper part of this back wall there must be a square hole, three inches wide, and two high, for the vent of the chimney.

The furnace must then be roofed over with an arch springing from the front to the back, so that the height of the centre may be twenty-one inches above the grate.

When this furnace is used for distillation, two cylindrical earthen or cast-iron long necks, having cylindrical necks five inches long, and three inches and a half in diameter, are to be placed horizontally and parallel to each other, so that their bottoms may rest upon the ledge in the opposite wall, whilst their mouths lie parallel to the opening, *f*, they are put in at. The opening, *f*, is now to be perfectly closed up with brick and clay, leaving the necks of the vessels sticking out, to which earthen pipes or adopters being applied, and their other ends fixed into receivers, the operation may be thus begun. These receivers ought to be of a conical shape; for as only a very slight lateral deviation can be given to the cylinders, the great breadth of globular receivers of the same capacity would be inconvenient.

This furnace will raise a surprising degree of heat, and is at the same time safe and easy to manage. It likewise directs all the force of the fire upon the subject to be distilled, and may easily be regulated by means of the ash-hole. The learned professor informs us, that on trying to use cast-iron cylinders for the distillation of phosphorus from urine, he found they melted long before he had reason to expect the phosphorus

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Fig. 12.

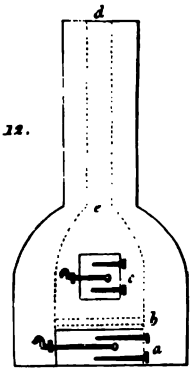


Fig. 1

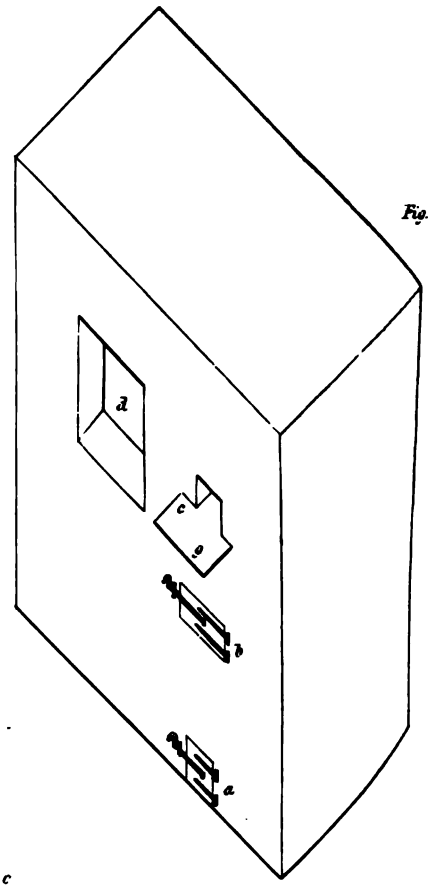
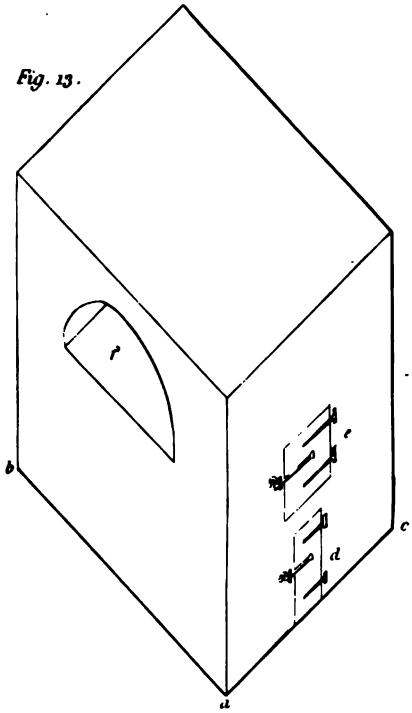
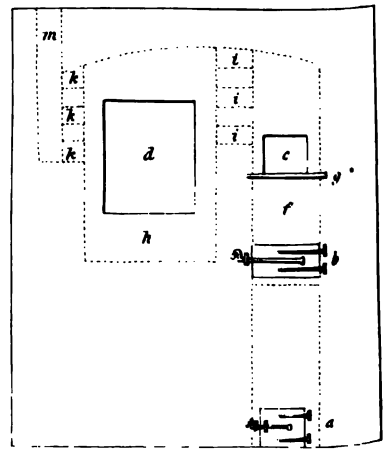


Fig. 13.





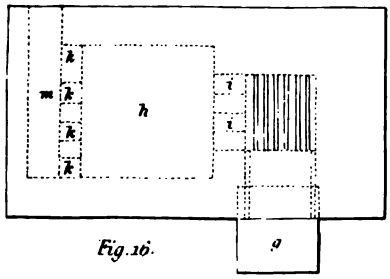


Fig. 16.

Fig 15

0 1 2 3 4 5 feet

to come over, whence we may form some judgment of the heat that this furnace will give when charcoal is used as the fuel.

Furnaces constructed upon the same principles as this reverberatory furnace invented by Boerhaave, are come into very common use, for various purposes, as will be seen in several parts of this work. They are used, for example, in preparing the nitric, muriatic, and pyroligneous acids, charcoal for gunpowder, gas for lighting rooms, and in several other instances.

Reverberatory-Furnace, with a side Chamber.

Another kind of reverberatory-furnace, with a chamber on the side, has been long in use in the mining countries, but was first attempted to be brought into the general laboratory by Cramer, the operator of Boerhaave, who published his Elementa, Artis Docimasticæ, as a supplement to the Elementa Chemiæ of his master. But as he conjoined it with a tower muffle-furnace, a sand-pot, and water-bath, the construction of the furnace was so complicated, that although it has been described in several English books on chemistry, there is reason to believe the furnace described by him has never been built in England: it is, indeed, a true Dutch toy, requiring to be built and attended by the chemist himself, as neither bricklayer nor any hired operator would enter into the minutiæ of its construction, or its management when in use.

Dr. Bryan Higgins discarded the additions of Cramer, and simplified its construction. In my Elements of Pharmacy his large reverberatory is described, the present is his small furnace of that kind, as it existed when I first went to his assistance as operator.

Fig. 14, represents this furnace in perspective, which is about four feet two inches wide, two feet three inches from front to back, and four feet nine inches high.

Fig. 15, is a geometric elevation of the front.

Fig. 16, is a plan,—all drawn on a scale of half an inch to a foot.

The ash-room, *e*, and fire-room, *f*, are prismatic cavities of nine inches square, with walls of the same thickness, having the ash-room entrance level with the ground, with a door six inches square, and a stoking-door, *b*, nine inches wide, and four inches high, just above the grate, which is one foot nine inches from the ground. Above the stoking-door is a feeding-door, *c*, five inches wide and four high, with a square ten-inch slab, *g*, of cast-iron, to support the small coal used for stopping it. All these openings may be either in the front or side of the furnace.

The chamber, *h*, is separated from the fire-room by a wall, half a brick, that is, four inches and a half thick, which has, towards the roof of the furnace, several holes, *i*, two inches square, placed in quincunx, or chequer-ways, through which the flame and heated air passes into the chamber. Its ground-plot is eighteen inches square, and its floor two feet from the ground: the front and back walls are four inches and a half thick, but that opposite the fire-room, a whole brick, or nine inches thick. An opening, *d*, fifteen inches high and

twelve wide, is to be left in the front wall of the chamber, the lower edge being two feet six inches from the ground, and the opening surrounded by a frame of flat iron bars.

In the substance of the side wall of the chamber, opposite the fire-room, a channel, *m*, is made, into which a number of vent-holes, *k*, similar in size and number to those which conveyed the flame, &c. into the chamber, at the other end open; and this channel opens into the flue of the chimney.

To use this furnace with retorts, bricks are put into the chamber to form a support for them, and the large opening through which they were introduced is then closed with pieces of brick cemented with clay, or if no great heat is intended to be used, with moistened ashes.

If the substance to be distilled is apt to froth when heated, the fire must be applied from above downwards; in this case, the retort being fixed upon bricks, the remainder of the chamber up to the level of the substance in the retort is to be filled with sand, and when the large opening is filled up, two holes are to be left, one at each of the corners. The fire being then applied, and the distillation begun, the sand is to be gradually drawn out by an iron hook through these holes, by which means the retort is gradually uncovered as the distillation advances, and the vapours have not got to force their way through a mass of cool matter.

Crucibles with compositions for glass or pastes, seggars with pottery or porcelain-ware, cement-pots, calcining-dishes, or bone-ash tests for cupellation, may be placed in the chamber on a false floor of bricks; also a large muffle, or enamel kiln, and the opening bricked up, leaving one or two apertures for taking out trial pieces, or for inspecting the work.

Although this furnace is so useful, it is seldom found in general laboratories, but it is to be expected that its merits will be properly estimated, and that it will in future come into common use.

Several varieties of this furnace are employed for roasting and smelting ores; and for calcining kelp and other salts.

The Forge.

The forge and blast furnace are usually confounded together, although in fact very different.

The proper chemical forge, represented in Fig. 17, drawn on the scale of half an inch to a foot, is a massy piece of brickwork, *a*, about three feet square and two feet high, the back part of which has a wall, *b*, of half a brick in thickness, raised up about eighteen inches higher.

On the upper part of the hearth, next the brick wall, there is a square pit, *c*, of twelve inches square, and six inches deep. A channel, *d*, of about two inches square, leads from the middle of the bottom of this pit, sloping to the front, where it opens about three inches from the ground.

The back wall has a twere hole, *e*, being a long narrow slit of the width of the twere-pipe, and so high as to allow this to be placed at different angles, so

Fig. 17.

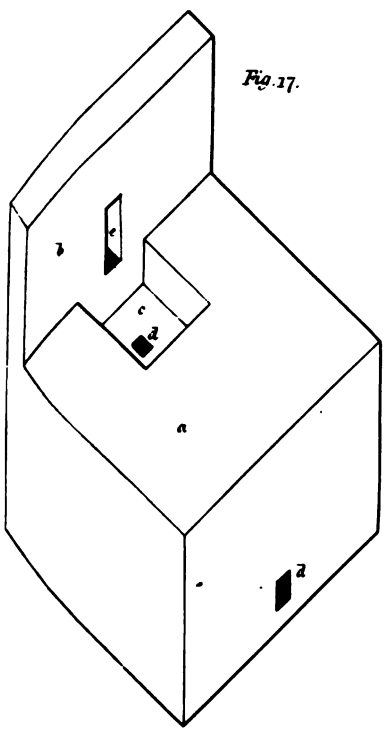
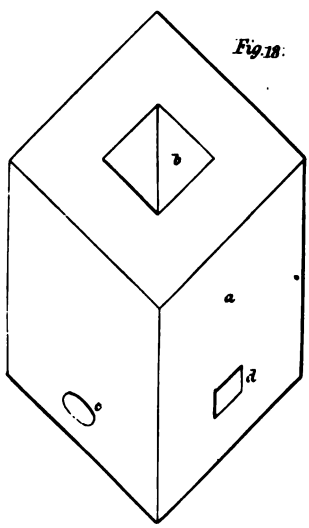
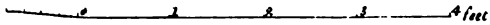


Fig. 18.





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as either to blow horizontally over the whole surface of the hearth, or at an angle of such obliquity as to direct the blast to the lower edge of the pit.

In the most general use of the forge, the pit is filled up with bricks, and the blast directed horizontally on the flat hearth. When caking-coal is used for fuel, care is taken to preserve a large cake to serve as a kind of vault to reverberate the heat; and to encourage the coals to cake, they are occasionally sprinkled with water.

The forge is sometimes used to melt substances in crucibles; two are in this case usually employed, and they are set upon a piece of brick about an inch high, not exactly opposite the blast, but so that it may pass between them, and the heat is confined by a few bricks being placed at a little distance, so as to form a semicircle.

In some operations on metals, the pit of the forge is filled with moist clay, mixed with charcoal powder into a stiff mass, and a hemispherical hollow, of about eight inches diameter, is formed in it. This is dried by making a small fire in it, and then, when sufficiently heated, the ore, or metal is added. After the operation is over, the materials are either laded out, or left to cool in the pit, or a hole is made with a poker, in the bottom, and the metal is allowed to run through the channel into a vessel placed in the front of the forge for that purpose. In this mode of operating, the twere-pipe is directed downwards, with a greater or less slope, as circumstances direct. The more it slopes the stronger is the heat.

The forge is frequently used to kindle a fire in a hurry, and is superior to any close furnace when vessels and materials require to be taken from the fire quickly, and as speedily replaced. It requires to be placed under a hood, or chimney, to carry off the smoke and vapours.

Blast Furnace.

The blast furnace agrees with the forge in being supplied with air by means of double bellows, but it has a grate, or a plate with holes serving for the same purpose.

The blast furnace is represented in Fig. 18, drawn on a scale of half an inch to a foot, and is externally of a cubical form, *a*, about two feet and a quarter each way. As the walls are a brick thick, the internal cavity, *b*, for the fire, is nine inches square, or, which is still better, circular, and about ten inches over, and goes down within three inches, or a single course of bricks, from the ground. The round furnace is usually made bellying in the middle to allow more room for the crucible.

There are two openings made at the bottom into this furnace. The first, *d*, is in the front of the furnace, about three inches square, and furnished with a piece of brick fitted to it. The other hole, *e*, is on the side, about six inches from the ground, to admit the blast pipe from the bellows.

When this furnace is to be used, an iron trivet, about eight inches high, is

to be put down the mouth of the furnace; and on this is to be placed, if the fire-room is circular, a cast iron plate with a double circle of round holes, one inch over; or if the fire-room is square, a grate, the bars of which are to be an inch wide, with spaces of the same width between them. A block of brick is placed on the grate, and on this is put the crucible; the furnace is then filled with fuel, and, being lighted at top, the door at bottom is left open until the whole of the fire is lighted and the crucible properly annealed.

The entrance for air is then closed by the brick and some moist clay, the mouth also partly closed by a couple of bricks to confine the heat, and the blast let on at first gently until the operation is nearly finished, and at last a strong blast of the utmost power of the bellows is usually given for about a quarter of an hour.

This furnace is not much used in small laboratories in England, and the founder's furnace is generally preferred in its room, partly on account of the trouble of blowing. The blast furnace has, however, some advantages, such as its not requiring a high chimney, which will frequently oblige a chemist to have recourse to it for exciting a great heat.

As soon as the bellows of small blast furnaces cease working, a cock, placed for that purpose on the blast-pipe, should be shut to prevent the hot air from rising into them, and causing the leather to crack.

The forge bellows must either be placed in a frame so constructed that they may be raised and lowered at pleasure, or if they are fixed in the upper part of the laboratory, which is most usually the case, in order that they may be out of the way of the operator, then the pipe must be made for some length, of leather hose, that its flexibility may allow the end to be altered in its height: in either case, the handle must be to the left of the operator.

In metallurgy on a large scale, the blast furnace is frequently used, and is, by the iron masters, made of an enormous size, even to that of seventy feet in height.

DISPOSITION OF FURNACES IN A LABORATORY.

Authors on chemistry do not often give any directions or plan to lay out a laboratory, nor show the mode in which fixed furnaces are connected together, when the chemist intends to devote a room for general chemical purposes. A few authors, however, have not omitted this very necessary information, and have given plans, elevations, or views of their own laboratories.

The principal difference consists in the dispositions of the chimneys. Barchusen, Pepys, and Thenard, place all their furnaces against the wall, under hoods, and the two latter have separate flues and chimneys for each furnace, or for two or three at most. Dr. Higgins, and the Society of Apothecaries, place the chimney in the centre; the first using several separate flues, the latter one single flue for all the furnaces.

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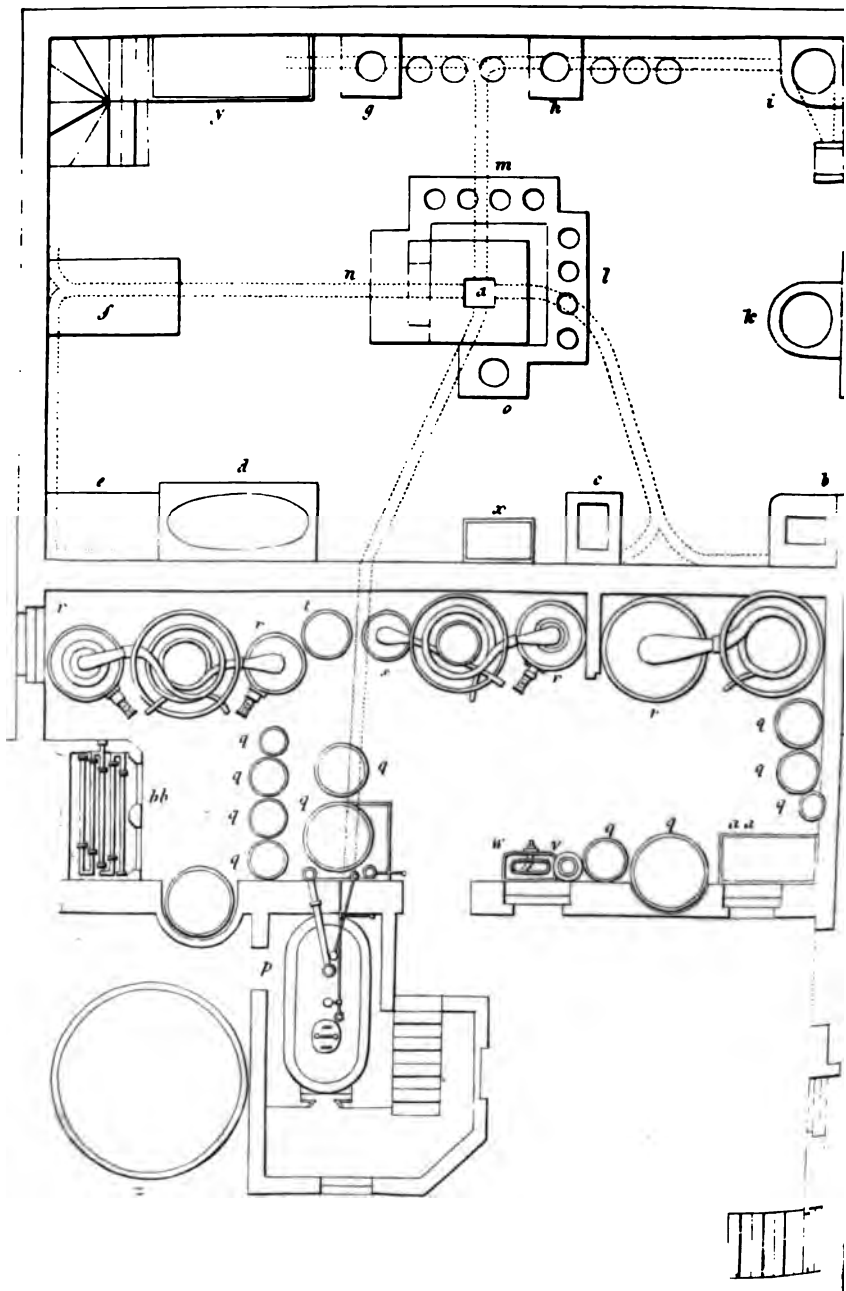
ASTOR, LENOX AND
TILDEN FOUNDATIONS
R L

Fig. 10. Pl.



London Society of Apothecaries' Laboratory.

The principal laboratory is a brick building, (Fig. 19.) about fifty feet square, and thirty high, lighted from above, and subdivided, by a brick wall, into two compartments. The dimensions of the larger one being fifty feet by thirty, and of the smaller, fifty feet by twenty. The former may properly be termed the Chemical Laboratory, all the open fires and furnaces being situated in it, and all operations requiring intense heat being there conducted. The latter is usually termed the Still-house, all distillations and evaporation being performed there exclusively by steam, most of which is furnished by a boiler placed in a small building annexed to the main laboratory.

The principal entrance to the Chemical laboratory is through the mortar-room, which is forty feet long and twenty-two broad, and appropriated to mortars, presses, and, generally speaking, to all mechanical operations performed by manual labour. At its eastern extremity is a large drying-stove, heated by flues, for the desiccation of those articles which cannot be dried conveniently at temperatures easily obtained by steam.

In the construction of the new laboratory, safety is ensured, as the whole is made fire-proof, by being lined with sheet-iron wherever it is necessary, and it is ventilated by a series of apertures in the roof, which may be opened or closed at pleasure. The main chimney, *a*, is erected in the centre; and has opening into it below the pavement of the laboratory, four large flues, one of which enters upon each side of its square base. The shaft is one hundred feet high from the foundation, and is accessible in its interior, from one of the under-ground flues. The flues of the furnaces, which are placed against the walls of the laboratory, are each supplied with registers, and open into a common channel which surrounds the building, terminating in the chimney, as already described. Each of the four large flues has also a register, which may be more or less closed or opened, according to the operations which are going on in the various furnaces connected with it.

The furnaces thus arranged, are,

B, a subliming apparatus for benzoic acid.

C, a furnace for the preparation of sulphate of quicksilver, with two descending flues communicating with the chimney; one for smoke, the other to carry off the sulphurous acid.

D, a high pressure steam-boiler.

E, a muffle-furnace was originally placed here, but it has been taken down, and a cistern of hot water supplies its place.

F, a large sand-bath, to work with several retorts at once.

G, an apparatus for distilling muriatic acid, with a file of three receivers connected together.

H, an apparatus for distilling nitric acid, with a file of three receivers connected together.

I, an apparatus for the distillation of hartshorn, with a cast-iron condenser

K, a circular calcining furnace, as it is called by Mr. Brande, but which is in fact nothing but a large stove-hole, about three feet in diameter, without either vent into the chimney, flue, or even a hood over it. This hole is used to calcine magnesia, but as it is heated partly with raw coals, it so fills the laboratory with smoke, that the fire is only lighted in the evening, when the operators leave off work, and left to itself.

There are also a series of furnaces built against the sides of the main chimney, and communicating directly with it, by flues of their own, which, as well as the common openings by which they enter the chimney, are supplied with effectual registers, so that when not in use, they may be perfectly closed. Of these furnaces, eight, *l*, *m*, are chiefly employed for various sublimations and fusions, or for retort pots; the third side of the chimney is occupied by a powerful wind-furnace, *n*, and the fourth by a furnace, *o*, for the sublimation of calomel.

The steam laboratory is supplied from two boilers, the largest of which, *p*, placed in a building separate from the laboratory, is an eight hundred gallon boiler, of the common wagon shape, made of copper, and works an engine of eight-horse power, at a pressure of an atmosphere and a half; consequently the steam produced by it has a temperature of 230 degrees. A forcing pump is also annexed to the engine, by which the boiler is occasionally supplied with hot water, resulting from the condensation of the steam in the various vessels.

The main steam pipe, which is six inches in diameter, is conducted round the laboratory in a cavity of brick-work, covered by moveable cast iron plates, and is accompanied by a smaller pipe, which receives and conveys the water resulting from the condensation of the steam into a cistern properly supplied with valves, whence it is occasionally pumped back into the boiler. A small steam pipe, with a register cock, passes to each of the stills and evaporators, each of which sends off a condensed liquor pipe into the main for its reception.

Four of the twelve boilers and evaporators, *q*, are of pewter, one of iron, and seven of copper. Four of these boilers are capable of holding from 150 to 300 gallons each; four contain about one hundred gallons each; and four from ten to twenty gallons each. There are also some smaller vessels of the same kind generally used as water baths.

The stills are seven in number; four are of copper, *r*; of these the largest contains five hundred gallons, and has a distinct worm tub; two contains two hundred gallons each, and one contains 150 gallons. There is a pewter still, *s*, of about thirty gallons, and one of lead, *t*, for the distillation of ether. These five stills have two condensing tubs; lastly, there is a still, *u*, which with its head and worm, *w*, are entirely of stone ware: it is chiefly employed for distilling spirit of nitric ether.

With the exception of the leaden ether still, all the above vessels are heated by the circulation of steam upon their exterior, being enclosed in cast iron jackets, and having a space between the two of about half an inch in width, into which the steam passes from the main steam pipe by the register cocks, and from which the condensing pipes pass off. A blow cock is attached to each vessel to allow of the escape of the air when the steam is first turned on.

A large branch of the steam pipe circulates in five convolutions at the bottom of the drying stove, *b b*, so as to heat a current of air, which is made to pass through it, and another branch, rising perpendicularly through the pavement, is properly fitted with cocks and screws for the occasional attachment of leaden or other pipes for boiling down liquids in moveable pans and vessels.

The small boiler, *d*, in the laboratory, is calculated for the production of high pressure steam, with a pressure of a hundred pounds on the square inch, so that the temperature of the steam produced by it is very considerable. It is

applied in another part of the building to various purposes of evaporation, solution, decoction, &c. and in addition, it only supplies the ether still in the steam laboratory, which is heated by a coil of leaden pipes, by which the temperature requisite for the production of ether from alcohol and sulphuric acid is obtained.

The waste steam of these boilers is condensed into a large cistern of water in another part of the building.

Besides the distillatory and evaporatory apparatus there are also two large drying stoves heated by steam, and several wooden and other vessels for saline solutions, &c. which are occasionally adapted to the steam apparatus, and heated by a coil of leaden pipe.

X, is a sink with a supply of water.

Y, is a collection of coal and coke bins, for the immediate supply of the laboratory.

Z, is a gasometer, to collect the oil gas, which is made in another part of the building.

A a, is a marble table in the still-house.

Besides these two laboratories the society has also under the same roof, what they call a test laboratory, on a smaller scale, which cost about six hundred pounds to build; although it contains only a square sand-bath, a single stove hole, and a raised hearth paved at top with Dutch tiles, and having several gas-burners, over which are placed the retorts and other vessels supported on the common pillar-and-ring stand.

They have also a magnesia room, with four copper and three iron boilers, and several large vats for dissolving, precipitating, or crystallizing saline solutions.

The plan and description of these laboratories are sufficient to show that they are by no means so well constructed as might be expected. As to the steam laboratory, it can only be regarded as a mere show; for pharmaceutical operations do not, like those of the dyeing and printing businesses, require successive rapid boilings of different liquors in the same vessel. The danger of burning-to might have been as effectually guarded against by the use of water-baths when necessary; although not in so elegant a manner, or so compact a compass; but the Society has room enough, for since the unsuccessful attempt made by them to procure the supply of the army, they have lost that of the navy, which they had supplied for rather more than a century, and have let out a part of their premises to a printer.

PORTABLE FURNACES.

Persons who are not in possession of a sufficient space of ground are necessitated to adopt the use of smaller furnaces, which may be laid away when not in use.

Dr. Black's Furnace.

Dr. Black, Professor of Chemistry, at Edinburgh, invented a peculiarly simple portable furnace, which he used for almost every purpose; but which, notwithstanding its extreme elegance of form, has been much neglected, and inferior portable furnaces have had the preference given to them.

Fig. 20, represents the external form of this furnace, and Fig. 21, a section of it. The body of it is of an oval form, made of thin sheet iron, and closed at each end by a thick cast-iron plate. The upper plate, or end of the furnace, is perforated with two holes; one of these, *a*, is pretty large, and is often the mouth of the furnace; the other hole, *b*, is of an oval form, and is intended for screwing down the vent upon. The undermost plate, or end of the furnace, has only one circular hole, somewhat nearer to one end of the ellipse than the other; hence a line passing through the centre of both circular holes, has a little obliquity forwards. This is shown in Fig. 39, which is a section of the body of the furnace, and exhibits one half of the upper, and one half of the under nearly corresponding holes.

The ash-room, *c*, is made of an elliptical form, like the furnace, but is somewhat wider, so that the bottom of the furnace goes within the brim; and a little below there is a border, *d*, Fig. 39,) that receives the bottom of the furnace.

Except the holes of the damping-plate, *e*, the parts are all made close by means of a quantity of soft lute, upon which the body of the furnace is pressed down, whereby the joining is made quite tight; for it is to be observed that, in this furnace, the body, ash-pit, vent, and grate, are all separate pieces, as the furnace comes from the hands of the workman.

The grate is made to apply to the outside of the lower part or circular hole; it consists of a ring set upon its edge, and bars likewise set on their edges. From the outer part of the ring proceed four pieces of iron, by means of which it can be screwed on; it is thus kept out of the cavity of the furnace, and preserved from the extremity of the heat, whereby it lasts much longer.

The sides of the furnace are luted, to confine the heat, and to defend the iron from the action of it. The luting is so managed, that the inside of the furnace forms, in some measure, the figure of an inverted truncated cone.

To this furnace belongs a crow's foot, *f*, and a cast-iron sand-pot, *g*, with a cover, *h*.

Now to adopt this furnace to the different operations in chemistry, we may first observe, that for a melting furnace, we need only provide a covering for the upper hole, which, in this case, is made the door of the furnace. As this hole is immediately over the grate, it is very convenient for introducing, and examining, from time to time, the substances that are to be acted upon. The cover for the outer door may be a flat square tile or brick. Dr. Black usually employed a sort of lid made of plate iron, with a rim that contains a quantity of luting. The degree of heat will be greater in proportion as we heighten the vent, and to the number of holes we open in the damping-plate.

By this means the furnace may be employed in most operations in the way of assaying; and though it does not admit of the introduction of a muffle, yet, if a small piece of brick is placed upon its one end, in the middle of the grate, and if large

Fig. 20.

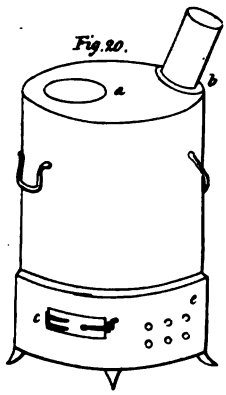


Fig. 21.

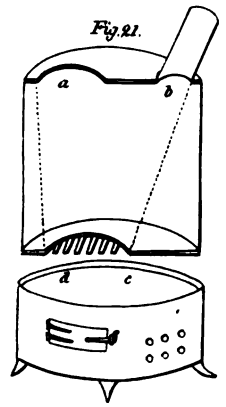


Fig. 22.

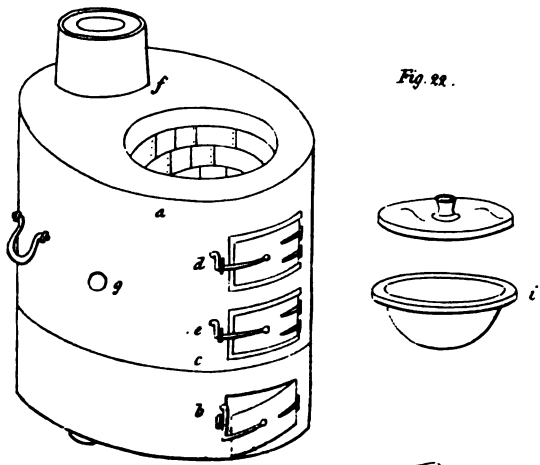
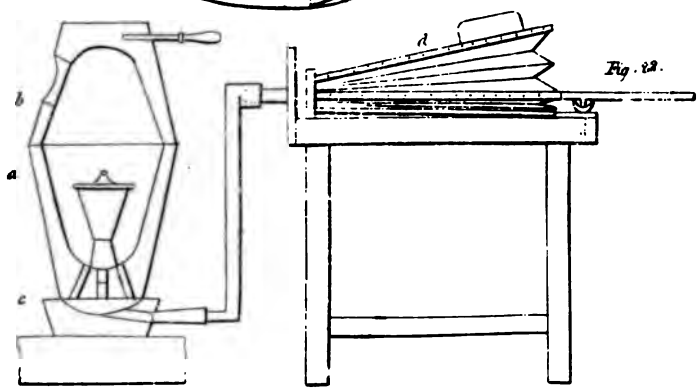
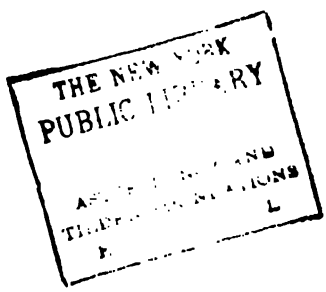


Fig. 23.

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ieces of fuel are employed, so that the air may have free pas-
ıge through it, metals may be assayed in this furnace without
oming in contact with the fuel. It may therefore be employed
ı those operations for which a muffle is used; and in this way,
ad, and sundry other metals may be brought to their proper
alces.

When we wish to employ this furnace for those distillations equiring an intense heat, an earthen retort is to be suspended, y means of a crow's foot, which has three iron branches bent ıp. This crow's foot, *f*, hangs down from the top hole about half ı foot; so that the bottom of the retort rests upon the meeting of he branches, and hangs immediately over the fuel. The open-ıg, between the mouth of the furnace and the vessel, is filled ıp with broken crucibles, or potsherds, and these are covered ver with ashes, which transmit the heat very slowly. This furnace then answers for distillations performed with the naked fire. Dr. Black had some of them provided with a hole in the side, from which the neck of the retort issued; and in this way he distilled the phosphorus of urine, which requires a very strong heat; but every opening on the side is to be avoided if possible.

For distillations with retorts performed in the sand-bath, there is an iron pot, fitted for the opening of the furnace *a*, and this is employed as a sand-pot, or capella vacua. In these distillations the vent becomes the door of the furnace, and it is more easily kept tight than when on the side. When it thus serves for the door, it may be covered with a lid of charcoal and clay.

This furnace answers very well too for the common still; part of which may be made to enter the opening and hang over the fire. In this case, likewise, the vent is the door of the furnace, by which fresh fuel is to be added. In ordinary distillations, it is never necessary to add fresh fuel; and even in the distillation of quicksilver, phosphorus of urine, and, indeed, during any process whatever, the furnace generally contains sufficient to finish the operation, so effectually is the heat preserved from dissipation, and the consumption of the fuel is so very slow.

This excellent furnace is too simple and chaste in its form to please the amateur chemist, or the common show lecturer on chemistry; and the necessity of using charcoal as fuel, tends to prevent its adoption among experimenters in England: hence it has never come into common use.

Knight's Furnace.

Mr. Knight has made an alteration in the construction of Dr. Black's furnace, which, by adapting it for burning pit-coal,

has caused it to be more usually employed than the original invention of the Edinburgh professor.

Fig. 22, represents an outline of the former. It consists of an oval iron case, twenty-two inches high, twenty in its largest diameter, and fifteen in its shortest; lined with fire-brick, or fire-clay, for about three-fourths of its height from the top, which part forms the body of the furnace, while the under part, which is not lined, forms a very spacious ash-pit, *A*, is the body of the furnace, which is cylindrical, but a little oblique, that the flame of the fuel may heat the sand more equally than if it were a straight cylinder. The breadth of this cylinder is eight inches and a half, and its height fifteen. The grate, *c*, lies across the bottom.

This fire-place has the following openings above the grate; the highest is the large opening at the top, which, when a sand heat is employed, receives the sand-pot, *i*, and when this is not wanted, is covered by a thick iron plate, lined with clay. The next opening is the elbow of the chimney, *f*, which widens as soon as it takes a perpendicular direction, and, for the first few inches, forms a part of the iron case of the furnace, and is lined with clay, after which it is elongated by an iron tube fitted to it, and not represented in the figures. The degree of heat is regulated by varying the length of this iron tube. The third opening, *e*, serves to introduce fuel, and may be employed also to regulate the heat. The fourth opening consists of two small round holes, *g*, opposite to each other on the two sides of the furnace. Through them a porcelain, or iron tube, is occasionally introduced, when it is required to be heated to redness for any particular experiment. The last opening, *d*, is intended for introducing a muffle, and serves also, occasionally, to feed the fire. All these openings are furnished with thick brick stoppers, and iron plates which slide over them. There are two openings, *b b*, in the ash-pit, which serve to regulate the draught of air, and, of course, to vary the heat of the furnace.

As the full depth of the fire-room is something inconvenient, a second loose grate accompanies the furnace, and a stand for it, composed of two rings, kept apart by three pillars at equal distances. When this stand is placed on the ordinary grate, and the loose grate placed upon it, the latter is just below the level of the lower edge of the upper door.

This furnace is very generally employed in England as a polychrest furnace, both by amateurs and experimenters. Its great fault is its weight, which requires two persons to move it; it also ought to be raised on the base of a brick work, or a strong table, in order to be employed as a muffle furnace, as otherwise the operator must lie down on the floor to inspect the matters in the muffle.

Aikin's Blast Furnace.

For the purpose of raising an intense heat in a short time, at an expense of very little fuel, Mr. Arthur Aikin contrived a convenient and cheap blast furnace, having taken up the idea of Dr. Lewis in his Philosophical Commerce of the Arts. This furnace is composed of three parts, all made out of the common thin black melting-pots, sold in London for the use of the working goldsmiths.

Fig. 23. The lower piece, *c*, is the bottom of one of these pots, cut off so low as only to leave a cavity of about an inch deep, and ground smooth above and below. The outside diameter, over the top, is five inches and a-half. The middle piece or fire-place, *a*, is a larger portion of a similar pot, with a cavity

about six inches deep, and measuring seven inches and a-half over the top, outside diameter, and perforated with six blast-holes at the bottom.

These two pots are all that are essentially necessary to the furnace for most operations; but when it is wished to heap up fuel above the top of a crucible contained, and especially to protect the eyes from the intolerable glare of the fire when in full height, an upper pot, *b*, is added, of the same dimensions as the middle one, and with a large opening in the side, cut to allow the exit of the smoke and flame. It has also an iron stem, with a wooden handle (an old chisel answers the purpose very well) for removing it occasionally.

The bellows, which are double, *d*, are firmly fixed, by a little contrivance which will take off and on, to a heavy stool, as represented in the plate; and their handle should be lengthened so as to make them work easier to the hand. To increase their force, on particular occasions, a plate of lead may be firmly tied on the wood of the upper flap. The nozzle is received into a hole in the pot, *c*, which conducts the blast into its cavity. Hence the air passes into the fire-place, *a*, through six holes of the size of a large gimblet, drilled at equal distances through the bottom of the pot, and all converging in an inward direction, so that, if prolonged, they would meet about the centre of the upper part of the fire.

No luting is necessary in using this furnace, so that it may be set up and taken down immediately. Coke, or common cinders, taken from the fire, when the coal ceases to blaze, sifted from the dust, and broken into very small pieces, forms the best fuel for higher heats. The fire may be kindled at first by a few lighted cinders, and a small quantity of wood-charcoal.

The heat which this little furnace will afford is so intense, that its power was at first discovered accidentally by the fusion of a thick piece of cast iron. The utmost heat procured by it was 167° of Wedgewood's pyrometer, when a Hessian crucible was actually sinking down into a state of porcelaneous fusion. A steady heat of 155° or 160° may be depended on, if the fire be properly managed, and the bellows worked with vigour.

This is a very convenient furnace for fusion when a person has not a proper blast furnace or forge.

French Evaporating Furnace.

The portable furnace, called by the French, *fourneau evaporatoire*, is used for evaporating liquids, and the performance of other operations that require only a slight degree of heat.

Fig. 24, represents this evaporating furnace, or chafing dish, as we should call it; *a*, is the fire-room; *b*, the ash-room, to receive the ashes; *c*, the entrance into the fire-room, furnished with a stopper to rest on the slab; *d*, the entrance into the ash-room, having also a stopper; *e*, outlets by which the draught is maintained when the top of the furnace is closed, by a dish or kettle of larger diameter than the fire-room being placed upon it.

This furnace is always made of a single piece of stone-ware, and has generally, instead of a grate, a flat plate of the same ware, with round holes. The charcoal or other fuel is usually put in at the top, but sometimes on the side.

French Reverberatory Furnace.

The portable furnace, called by the French *fourneau à réverbère* is used to expose substances to a greater degree of heat than can be produced in the last-mentioned furnace. The vessels used in it are almost always earthen retorts or crucibles.

Fig. 25, represents this common reverberatory furnace, known in Germany by the name of Becher's furnace; *a*, is the fire-room; *b*, the ash-room; *c*, the

entrance into the fire-room, with a stopper resting upon a slab for that purpose; *d*, the entrance into the ash-room, with its stopper; *e*, the chamber separated from the fire-room by two iron bars, resting upon notches made in the upper part of the fire-room; *f*, the dome or cupola of the furnace, serving to reverberate the heat upon the retort when the furnace is used for distillation; *g*, a circular opening cut partly in the chamber of the furnace, and partly in the dome, to allow a passage for the neck of the retort; *h*, *n*, handles for conveniently moving the furnace. Those parts of the furnaces that are exposed to the greatest heat are sometimes bound with hoops or iron wires when the sides are not made sufficiently strong; *i*, the vent, upon which is occasionally, but rarely, placed a chimney of the same ware, three feet in height.

These two, or rather the last only, are almost the only furnaces used commonly in the laboratories of the French chemists. The chimney of the reverberatory is sometimes heightened by an iron pipe of six or nine feet in length, to augment the draught; and at other times the blast of a pair of double bellows is thrown into the fire, by a flexible pipe communicating with the bellows.

When uncoated glass retorts are used for distillation, the French chemists place on the iron bars that part of the fire-room and chamber, a sand-pot made of sheet iron, about an inch less in diameter than the internal cavity of the furnace, and having a notch in its side, which answers to the notch in the chamber. This sand-pot is placed as close as possible to that side of the furnace where this notch is situated, and the neck of the retort guarded from the heat by some clay stuffed between the pot and the furnace. The sides of the pot ought to be an inch higher than the arch of the retort, that it may be entirely covered with the sand, to defend it from the too great heat that might be reverberated upon it by the dome, which the French chemists are in the habit of using with the sand-pot. Earthen and cast iron sand-pots are thought by them to waste fuel, on account of their thickness.

For distilling with a large stone-ware body, it is placed on the two bars, and the dome being put on so that the neck of the body comes through the vent, *i*, and rises about two or three inches above it, a glass head is then luted to the body, and the space between the sides of the vent and the neck of the body stopped up with clay. In this case the notches, *g*, in the chamber and dome, serve as a vent. The French usually distil water, and vinegar by this apparatus. Instead of a body and glass head, a stone-ware bottle, stopped by a cork, and having a glass pipe passing through the cork, and properly bent so as to convey the vapour into a glass carboy, placed by the side of the furnace, is now more commonly used.

Macquer's Reverberatory Furnace.

There is also another portable reverberatory furnace sold in Paris, and distinguished by the name of its introducer, the ce-

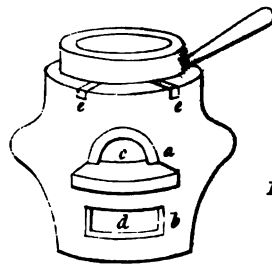

Fig. 24.

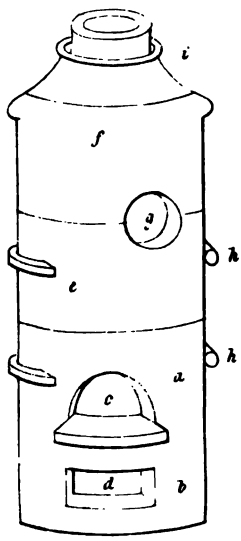

Fig. 25.

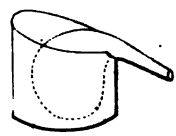

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Fig. 26.

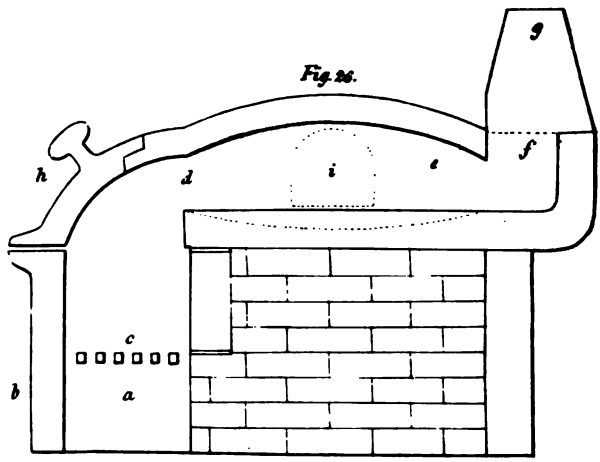


Fig. 27.

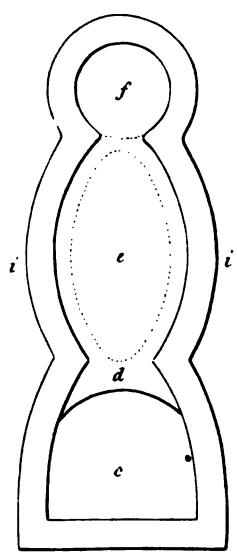
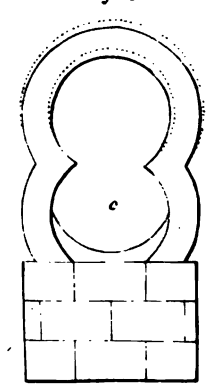


Fig. 28.



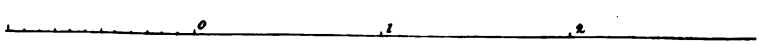


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Fig 29

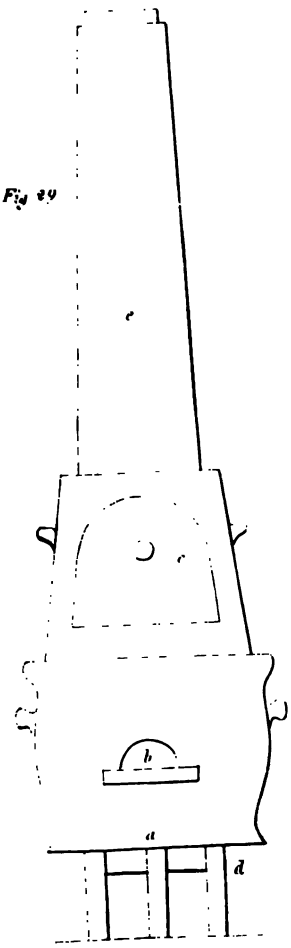
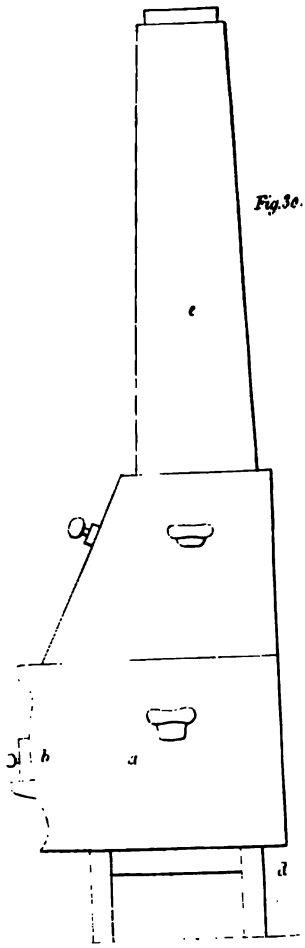
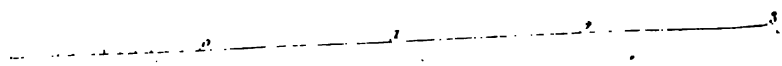


Fig.30.





lebrated Macquer. In this furnace the chamber is on the side.

Fig. 26, represents a plan of this furnace on a scale of about an inch to a foot; Fig. 27, the longitudinal section; and Fig. 28, the transverse section of the chamber, in which the laboratory is made to rest on bricks set for that purpose;—*a*, is the ash-room, about nine inches deep from front to back, seven inches wide, and eight inches high; *b*, the entrance to the ash-room, closed with a stopper; *c*, the fire-room, with its grate; this room is of the same size as the ash-room, but the sides bulge out so as to enlarge its width to eight inches in the middle of its height; *d*, the throat, or passage, for the flame into the chamber; this is only five inches and a half wide at bottom, and arched at top; *e*, the chamber is of a long oval figure, about two feet in length, seven inches wide, and five high in the middle, and only three inches and a half wide, and as many high at the vent, *f*. The bottom plate of the chamber is full two inches thick, and its upper surface is hollowed out into a shallow basin. The flue, *g*, is circular, and five inches in diameter; over it is occasionally fitted an earthen chimney, two feet in height, lengthened, when necessary, by an iron pipe eight or nine feet long. The roof of the chamber is extended forward so as to cover the fire-room with half a cupola, in which is left a large feeding-door, *h*, closed with a stopper. The chamber has also two openings, *i*, *i*, one on each side, the largest for to introduce vessels or materials, and the smallest for the purpose of inspecting the progress of the operation or admitting air.

The many uses to which this furnace may be applied will be easily conceived by an experienced chemist, and by others they may be gathered from what has been said in p. 85, respecting the furnace with a chamber on its side.

Macquer's Lithogeognosic Furnace.

Dr. Macquer has described another furnace in the Memoires de l'Academie des Sciences, for 1758, which is used in Paris when operations requiring intense heat are to be performed, under the name of the *fourneau lithogeognosique de M. Macquer*, it being copied from the wind furnace figured by Mr. Pott in his Lithogeognosie.

Fig. 29 and 30, show the front and side view of this furnace, as given by Baumé in his Chymie Experimentale et raisonnee. All the dimensions are not mentioned, and are here stated from their proportion to those parts whose admeasurements are known.

The fire-room, *a*, is entirely open at bottom, except a ledge of an inch and a half all round to support the grate, which is composed of seven bars placed with an edge uppermost, at half inch distances. The inside measure was eleven inches from side to side, and thirteen inches from front to back. There is no ash-room, as it merely stands upon a trivet, *d*, six inches high, so that the air has free access to the fire on all sides.

Three inches and a half above the surface of the grate, or five inches from the bottom line, is the opening into the fire-room, *b*, at which a muffle was usually introduced. This opening is semicircular, and described by a radius of one inch and a half, hence it is three inches wide at bottom. A stopper is fitted to this muffle door. It must be observed that the fire-room bulges on the sides so as to allow more space between the muffle and the side walls for the fire.

About six inches above the muffle door, the front and sides of the furnace slope, so that at the height of about a foot the fire-room is contracted to about eight inches square on the inside; but the back wall rises perpendicularly. This sloping part or dome, is made of a separate piece of stone-ware.

quart of water to each pound. Some charcoal, a part of which is lighted, is then put upon the iron dish, *g*, and the large boiler is put into the furnace, so that three little projections near its rim do not fit into their correspondent openings in the double vessel; by which means a passage is left for the air, which has entered at the hole, *h*, in the bottom of the furnace, and acted upon the charcoal, to escape. The small boiler is fitted into the mouth of the other, and in about thirty-six or forty minutes, the water in the double vessel begins to emit steam at the end, *m*, of the steam-pipe, *l m*, which shows that the water in the large boiler has attained nearly a boiling heat.

The small boiler is then taken off, the broth scummed, the vegetables and salt put in, and the small boiler being replaced, the large boiler is turned so that the projections on its rim fit into their places, and the passage of any air through the fire stopped; the slider is also shut, and the whole covered with the blanket, to retain the heat. In about six hours the soup is considered as being sufficiently cooked; there is also a quantity of hot water in the double vessel and the small boiler, to wash the dishes, or for any other purposes.

That excellent chemist, M. Thenard, is of opinion it would be better to have some very small holes in the slider, and that the large boiler should not fit accurately into the double vessel, in order to allow a very slow combustion of the charcoal to continue during the whole process.

The economy in using the caléfacteur is evident, as, on an average, ten avoirdupois ounces of charcoal, is sufficient for cooking six pounds of meat into nine pints of soup.

Thirteen quarts and a-half of water, at about 71 degrees of Fahrenheit, being put into the double vessel and small boiler, and fifteen quarts and a-half in the large boiler, and two pounds of charcoal in the iron dish, was left for three hours and three-quarters; the fire was then stifled by shutting the slider, and on being taken out, it was found that about three ounces were left unconsumed. Six quarts and about a third had steamed away, so that reckoning the heat communicated to the furnace and boilers, weighing altogether nearly twelve pounds, the heat had produced nine-tenths of its maximum theoretical effect.

The principle adopted in this furnace, of having the fire within the boiler, had been already used by Mr. Trevethick, in the boilers for his high-pressure steam-engines. It is also, as we learn from Kæmpfer, in universal use in Japan for the tea-canteens, in which all persons in easy circumstances carry hot water with them when on a journey, or party of pleasure, that they may refresh themselves at any time with a dish of tea, without going into any house of entertainment.

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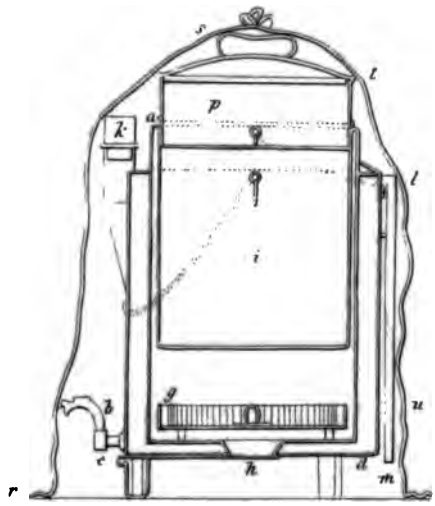
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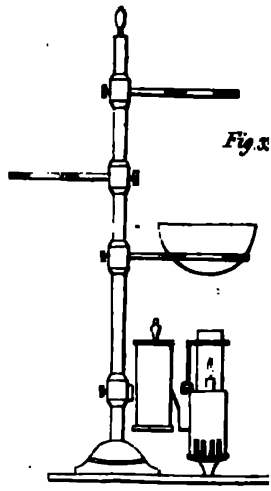


Fig. x

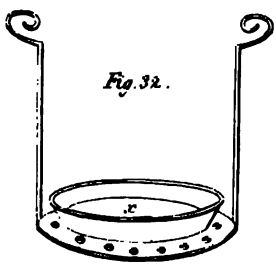
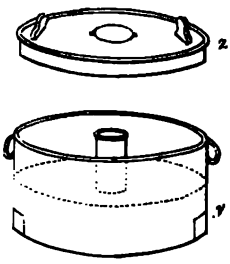


Fig. 32.
x


z
y

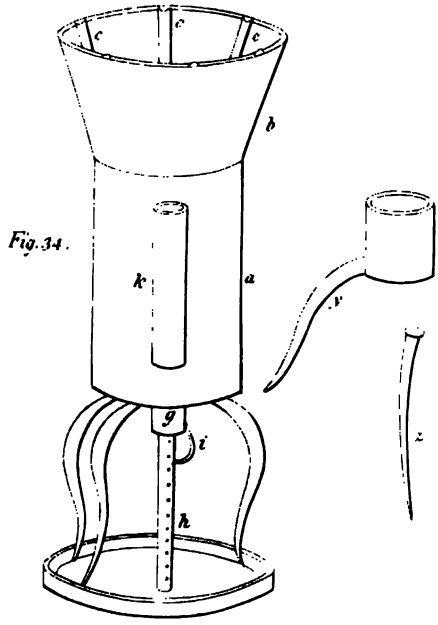


Fig. 34.
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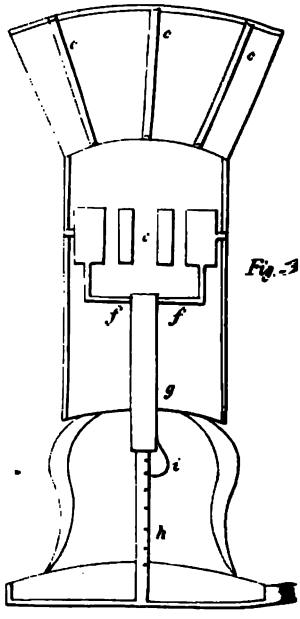
c
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Fig. 3

Fig. 32, represents some additional apparatus to the caléfacteur Lemare, to dopt it for the preparation of roast meat, that is to say, what the Parisians unlerstand by that name.

W, is an iron support, with two handles, to let down into the caléfacteur intead of the boiler, *i*, to support the shallow iron frying-pan without a handle, r, about three inches above the charcoal on the grate, *g*.

The upper boiler, *p*, is replaced by another, *y*, of a different form, a couple of notches in its sides allows it to pass the handles, *w*, of the support of the oasting-pan, above these notches, it has a bottom and a vent-pipe through its niddle for the vapour of the meat. This boiler, like the two others, may be livided into two or three partitions, in order to cook several different dishes at he same time. It has a cover, *a*, which fits very close, and has a hole in the middle, answering to the vent-pipe, which is closed at pleasure by a sliding plate.

It is asserted that this caléfacteur, or portable kitchen, will reverberate the heat sufficiently to roast the pieces of meat, or poultry, placed on the iron pan, *x*; and when the meat is done enough, by closing the register, *c h*, at the bottom of the caléfacteur, and the vent-pipe in the boiler, *y*, the charcoal is extinguished, and the roast meat may be kept in a proper state for serving up an hour or two afterwards!

The materials of which this furnace and its boilers are made are not stated in the book from which this account is extracted; the prices, as quoted for Paris, seem rather dear, a caléfacteur for one pound of meat, 15*s.*; for two pounds, 18*s.*; for three pounds, 22*s.*; for four pounds, 27*s.*; and for five pounds of meat, 32*s.*

LAMP FURNACES.

For chemical experiments upon a small scale the spirit lamp is by far the most convenient kind of lamp, as the flame of spirit of wine does not blacken, or in any degree soil the vessel to which it is applied; and as the degrees of heat may be regulated merely by raising the lamp higher up, or by placing it lower down, any short small glass bottle may be made to answer for a spirit lamp; but, in order to prevent waste of the spirit by evaporation, the spirit lamp requires to have a glass cap fitted to it by grinding, so as to enclose the wick air-tight.

An Argand's lamp sliding on a pillar, which has also two or three rings sliding on it, represented at Fig. 33, is very frequently employed at present for evaporations, and similar operations which do not require any great heat.

Both these lamps have, however, the inconvenience of wasting the far greater part of the heat from the free access of the cold air on every side: and the heat is also confined to a single point of the vessel, so that only liquids, or at least solids, fusible by the heat to which they are exposed over the lamp, can be properly operated upon with this apparatus.

Dr. Percival's Lamp Furnace.

The first objection to lamp furnaces has been removed by

Dr. Percival, but the second is not avoided in his lamp furnace.

Fig. 34, represents Dr. Percival's chamber lamp furnace, of which a section is shown in Fig. 35. It consists of a cylindrical body, *a*, about four inches in diameter, and nine and a-half high, surmounted by a laboratory, or space for containing vessels, which is a hollow truncated cone, *b*, six inches and a-half wide at top, and four at bottom. Its conical shape adapts it to vessels of different sizes. To the inside of the laboratory are riveted six tubes, *c*, one-quarter of an inch diameter, in which the vessel rests, so that space sufficient for the passage of heated air is interposed between it and the inside of the laboratory. Into three of these tubes, iron spikes, *z*, previously fitted to them, are occasionally introduced: their converging extremities form a support for vessels, the bottoms of which are less than four inches in diameter.

In one of these tubes, *c*, whilst the lamp is burning, is placed the small pipe, *y*, which, communicating with the reservoir, supplies oil gradually to the lamp, through an aperture contrived for that purpose. The lamp, which is contained in the body of the furnace, is made according to Argand's construction, with an oil cistern, which is a hollow cylinder. The diameter of the wick-holder, in the clear, is one inch and a half; the diameter of the interior circular air aperture, *e*, Fig. 58, is one inch and a quarter.

The lamp is supported by two cross stays, *f*, which are fixed to the top of the tube, *g*. This tube rises and falls on the stem, *h*, and is fixed at different heights by means of the spring-catch, *i*, which is fastened to the tube, and fits into holes made in the stem. The tube in rising and falling carries with it the lamp, which by this means may be supported at different distances from the vessels in the laboratory. The furnace itself answers the purpose of a chimney to the lamp.

In the body of the furnace is an opening, *k*, Fig. 34, for trimming the lamp: this may be closed by a slide. When it is closed, the heat of the lamp is considerably increased, for reasons too obvious to be insisted upon. The bottom of the lamp, to make it more steady, is loaded with lead.

To determine whether the heat produced would be greater, if the external air-aperture of the wick-holder were diminished, a stopper was made, half an inch in diameter, which fitting into the central aperture with a spring, left a circular opening three-eighths of an inch wide for the passage of air.

It was then observed with a thermometer and stop watch at what rate quicksilver, contained in a glass solution bottle which was placed in the laboratory, acquired temperature first, when the stopper was not employed, and afterwards when it was. The bottom of the vessel was one inch and seven-eighths distant from the edge of the wick-holder.

The result of these observations is contained in the following table. At the beginning of the observation, the thermometer placed in the quicksilver stood at 113.5.

Without Stopper.

Minutes of observation.	Temperatures.	Increments of temperature in a minute.
1	143.5	30
2	174	30.5
3	203	29
4	231	28
5	256	25

In five minutes, 142 degrees .5.

The stopper put in.

6	292	36

The increment of temperature in this sixth minute was diminished by lowering the slide for the admission of the stopper.

7	335	63
8	409·5	54.5
9	458	48.5
10	500	42

In five minutes, 244 degrees.

It is obvious that the effect of the stopper, in increasing the heat, must have been considerable; as, from the former part, it appears that as the temperature of quicksilver increases, the increments of its temperature in a given time, circumstances remaining the same, diminish; yet the sum of the increments, in the last five minutes, considerably exceeds the sum of the increments in the first.

The effect of diminishing still farther the internal air-aperture of the wick-holder was then tried: a ring being adapted to the stopper, it increased its diameter to seven-eighths of an inch, and consequently diminished the width of the circular opening for air to three-sixteenths of an inch.

The following table will show the effect of this alteration. In this experiment the lamp burnt less briskly than in the former. The temperature of the quicksilver at the beginning of observation was 113.5.

Without Stopper.

Minutes of observation.	Temperatures.	Increments of temperature in a minute.
1	135	21.5
2	157.5	22.5
3	177	19.5
4	196	19
5	213	17

In five minutes, 99 degrees .5

The enlarged Stopper put in.

6	247	34
7	329	82
8	402.5	73.5
9	468	65.5
10	524	56

In five minutes, 311 degrees.

As the proportion of 311 to 99.5 is much greater than that of 244 to 142.5, the enlarged stopper appeared to have considerable advantage in increasing the heat.

The comparative effect of the two stoppers was determined by another trial, and it is shown in the following table:

Lamp with enlarged Stopper.

Temperature of quicksilver 125.

Minutes of observation.	Temperatures.	Increments of temperature in a minute.
1	175	50
2	228	53
3	274	46

In three minutes, 149 degrees.

Lamp with small Stopper.

Temperature of quicksilver 125.

1	170	45
2	214	44
3	254	40

In three minutes, 129 degrees.

Thus it appears that in lamps made on this construction, the internal aperture for air may be considerably diminished with advantage. What is the most advantageous opening has not been determined; but it is probable, that it would not bear to be diminished much more than in the experiment last recited.

Baumé's Lamp Sand-bath.

M. Baumé's lamp-furnaces are superior to any of the preceding, for the purpose of distillation by a gentle heat, by a bath of water, or sand. He justly observes, that as lamp-furnaces require less attention than those in which wood, or other fuel is burned, they suit the convenience, and meet the approbation of many persons.

M. Baumé constructs his lamp-furnaces of thin sheet-iron, and uses common olive-oil, or Galipoli-oil, as it is also called; but any other oil, which does not give out much smoke in burning, may be also used. Four, five, or six wicks, either of cotton, amianthus, or gold wire, may be put into the lamp, and only so many of them lighted as may be sufficient. The wicks are easily arranged by scissors and spring forceps.

Fig. 36, represents M. Baumé's lamp-furnace, as fitted for a sand-bath; *a*, is the body of the furnace, made as above stated, of thin sheet-iron, and having towards the bottom three or four openings, to admit the air. It has also an arched opening at *b*, to allow the branch of the lamp which contains the wicks to enter the body of the furnace; *c d*, is the lamp itself; *c*, being a glass reservoir for oil, such as is usually sold by the bird-cage makers for bird-fountains in aviaries, but furnished with a tin plate valve at its mouth, to prevent the oil from running out, while it is being taken away, or put into the bottom, *d*, of the lamp; though this may be dispensed with if the party does not mind greasing his fingers, and spilling a little of the oil. The bottom, *d*, of the lamp, is made of tin-plate, and has a branch, *b*, of sufficient length to enter the body of the furnace, and allow the wicks, which are disposed in two rows at the end of the branch, to be placed in the centre of the furnace.

At the top of the body, a sand-pot, *e*, of thin plate-iron, fits in and enters about two or three inches deep, a small flange, or pins are fastened round this pot, to prevent it from entering deeper into the pot. In this pot is usually worked a retort, *f*; to which is luted a receiver, *g*.

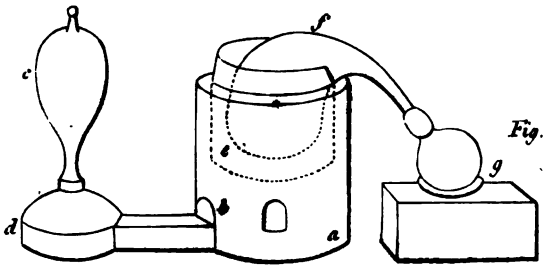


Fig. 36

Fig. 37.

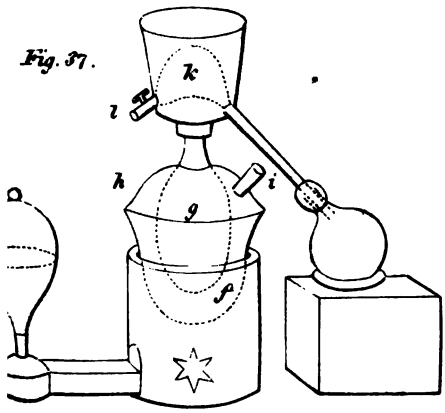


Fig. 39

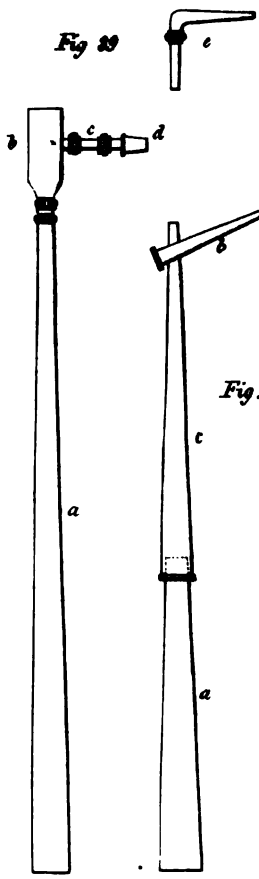


Fig. 40.

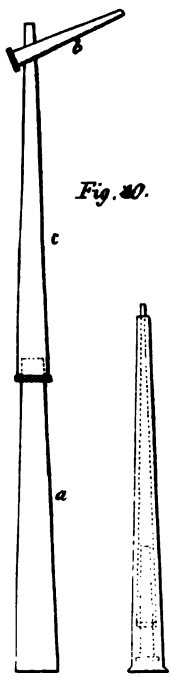
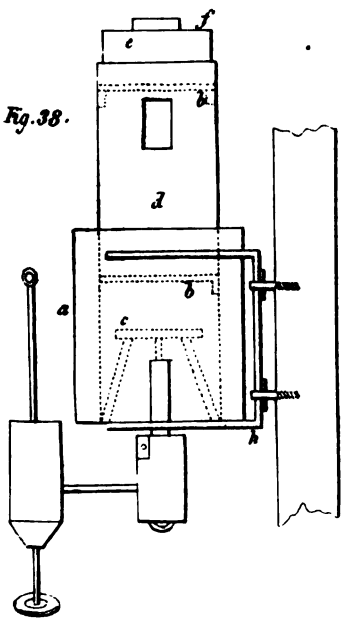


Fig. 38.



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In the lamp furnace thus fitted, many spiritous liquors may e distilled, several essential oils rectified, and many other perations performed.

Baumé's Lamp Water-bath.

The apparatus for adapting M. Baumé's lamp-furnace for istillation by the water-bath, is rather more complicated.

Fig. 37, exhibits the lamp water-bath of Baumé. The body of the furnace d the lamp, remains as before, but in place of the sheet-iron sand-pot, a tin-ate vessel, *f*, is fitted into the top of the body of the furnace, to hold the wa-r forming the bath, in which is plunged a glass or pewter body, *g*. A cover, that fits very close, is then put over the bath, which has a hole just big enough allow a passage to the neck of the body; and this cover has also a small pipe, to let the steam escape, and by which fresh water may be added as may be quired.

A glass head, *k*, is placed on the body, and generally luted with slips of pa-er, rubbed over with paste or starch. A refrigeratory, *k*, is often placed upon is head, and for the sake of being the better enabled to fit it to the surface of e head, this refrigeratory is made of milled lead, and has a small notch on one f its sides, to suit the enlargement of the head where the nose is placed. The ining between this refrigeratory and the head is secured, first by a small roll f fat lute, and, secondly, by a strip of linen, upon which a lute of cheese and uick-lime has been spread. A small cock, *l*, is soldered to the refrigeratory, hat the water, when heated, may be drawn off.

The fine spiritous perfumes may be distilled in this appara-us to great advantage.

Baup's Lamp Reverberatory Furnace.

In experimental researches, it is frequently necessary to dry he products completely, by the passage of heated air over hem in a kind of reverberatory, for which purpose D'Arcet's amp furnace is generally used in France.

M. D'Arcet's stove is described, in Thenard's Traité de Chi-nié, as consisting of a four-sided chest, made of very dry wood; ut the temperature could never be raised above the heat of oiling water, even after several hours. By the improvement f M. Baup, a chemist of Vevay, he has been able to dry sub-tances by a heat of 150 degrees cent, equal to 302 degrees ahrenheit, or even a little more.

M. Baup's stove, represented in Fig. 38, is cylindrical, of three pieces, each iece being composed of two pieces of pasteboard, glued together, so that here they join the two sheets of the first and second cylinders, may differ in eight, and that the projecting edges may fit into corresponding recesses in he lower edges of the second and third cylinders; by which means the pieces re kept steady one upon the other.

The lower, or first cylinder, *a*, of eight inches diameter, and twelve high, is losed at bottom by a circular piece of pasteboard, having a hole in the middle o introduce the glass chimney of an Argand lamp. It is also surrounded, at he distance of about two inches, with another cylinder, made of a single paste-oard. The space between the two cylinders is filled with carded cotton, or wool, and covered at top with a circular band of pasteboard. Near the top of

BLOW-PIPES.

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construction, with an additional bent b
blow-pipe, and to Wollaston's for a pock

this cylinder, a circle, or ring of pasteboard, is fixed, serving to support iron wire gratings, *b*, on which the substances to be dried are placed.

There is also a circular plate of iron, *c*, pierced with holes all round its border, and supported on three wires, placed in the lower part, which serves, like the mushroom in M. D'Arcet's stove, to prevent the heat of the lamp from acting on one point only, and to distribute it equally.

The first piece is surmounted by a second, *d*, about nine inches high, with a plate of glass fixed on one side. The top of this piece is also surrounded with a pasteboard ring, *b*, to support a wire grating.

The third piece, *e*, is only about three inches high, and is closed at top with a circular piece of pasteboard, having a circular hole in the middle, rather larger than the hole at bottom, to admit the chimney of the Argand's lamp: over this hole a plate of glass, *f*, is occasionally laid, to close the opening, more or less.

The stove itself is supported either by an iron frame, *h*, which may be secured against a wall, or by the rings of a common pillar-stand, of a large size, having its foot well loaded.

Before the outer cylinder was added as an envelope to the first cylinder, the heat on the lower grating could not be raised to more than 120 degrees cent, or 248 degrees Fahrenheit. When the outer cylinder was added, but left empty, the heat rose to 130 degrees, or 266 degrees Fahrenheit. The space between the cylinders being filled with charcoal, it took a longer time to arrive at 130 degrees, and the heat never went beyond it. But on filling the space between the inner and outer cylinder with wool, carded cotton, or feathers, the heat increased to 150 degrees, or 302 degrees Fahrenheit, and even to 160 degrees, or 320 degrees Fahrenheit, but less rapidly.

To procure the utmost effect of this stove, it is necessary to stop the space between the chimney of the lamp and the hole in the bottom of the stove with cotton or wool, and to close the opening at the top, as much as the necessary draught to prevent the lamp from smoking will allow.

This furnace may be considered as a lamp reverberatory furnace, or a miniature hot-air stove.

BLOW-PIPES.

The workers in gold and silver, and some other tradesmen, use a plain blow-pipe to melt the solders they employ to join different pieces of metal, but this instrument is so fatiguing to the lips and cheeks, when it is used for any continued blast, that the chemical mineralogists have attempted to make several improvements in its construction.

Gahn's Blow-pipe.

Berzelius, in a late excellent treatise on the use of the blow-pipe in chemistry and mineralogy, gives the preference to Gahn's construction, with an additional bent beak, for a laboratory blow-pipe, and to Wollaston's for a pocket instrument.

Gahn's blow-pipe is represented in Fig. 39. It consists of four pieces, *a*, *b*, *c*, *d*, which fit into one another very tightly. The cylindrical form of the chamber, *b*, destined to condense and collect the moisture of the breath, is far more advantageous than the forms given to this part by other chemists. By long wear, the end of the tube, *a*, will, indeed, enter farther into the chamber than at first, but this is no inconvenience; in other blow-pipes the chamber is liable to drop off the tube, or the joints to let the air escape.

Berzelius has found it convenient to add to Gahn's original construction, the bent beak, *c*, which, when inserted in the hole of the chamber, in the place of the original beak, *d*, can have whatever direction given it is necessary for glass-blowing.

The length of the tube ought to be such, that the substance on which the flame of the lamp is directed, may be at that distance from the eye of the operator, at which his vision is the most perfect.

Blow-pipes ought to be made of silver, or tin plate, with the beaks only of brass. When the tube and chamber are made of brass, they give out an ill smell, and have a coppery taste. Some endeavour to remedy these defects by an ivory mouth-piece, but still the smell remains uncorrected, and after some time the hands acquire a smell of verdigris, unless extraordinary care is taken of cleaning the instrument almost every time it is used. The joining of the tube with the chamber, if made of tin-plate, may be fully secured by wrapping a bit of paper round the tube.

The tips added to the beak are a great improvement; Berzelius has them made of platinum, for as they soon become filled with soot, and require the hole to be continually cleaned, he finds this the most advantageous metal, as he can heat them red with the blow-pipe, upon a piece of charcoal, and thus burn out the soot in an instant. It might be thought that silver tips would serve the purpose; but silver, when heated red, takes a crystalline texture on cooling, and becomes quite brittle.

Dr. Wollaston's Blow-pipe.

Dr. Wollaston has reduced the size of the blow-pipe to the very smallest, and by an ingenious contrivance, has brought it into the compass of a common pencil case, so that it may be carried in a pocket-book, along with a slip of platinum foil, and and a little borax, and thus enable the operator to make an instant examination of any suspected pharmaceutical preparation, or ill-assorted mineral in a collection.

Fig. 40, represents this blow-pipe of Dr. Wollaston, which is composed of three pieces, two of which, *a*, *c*, are of metal, the third, *b*, of wood tipped with metal, in order to afford a sufficient obstacle to the communication of heat to the first piece, *a*. The three pieces slide into one another, and are thus reducible to the smallest possible compass.

Berzelius observes that this blow-pipe is not adapted for those cases on which it is intended to examine the properties of substances with great care, because the pieces do not fit sufficiently well to prevent the loss of some of the breath; there is also no

reservoir for the moisture, and as the beak is placed at an obtuse angle on the stem, the direction given to the flame is such, that the body operated upon is in some measure hidden by the flame.

The best general support for bodies to be exposed to the blow-pipe is charcoal of soft wood, made by stifling, and sawed into small bars; charcoal made by distillation conducts heat so much better that it is totally unfit to be used as a support.

The blow-pipe, when skilfully handled, Mr. Children observes, is the most convenient chemical instrument for mineralogical researches, on a small scale, that has hitherto been invented. By its means we are enabled, in a few minutes, to determine the principal ingredients in any mineral submitted to our examination, even though it be composed of several elements. By merely directing the flame of a small lamp, in which olive oil is burned, on a fragment about the size of a large mustard seed, supported on a piece of charcoal, or a hook of fine platinum wire; most of the volatile substances, as sulphur, arsenic, zinc, cadmium, antimony, bismuth, and tellurium, may be detected.

Barytes will be known by the greenish yellow; and strontites by the crimson colour it imparts to the flame.

By employing only three flues, carbonate of soda, borax, and the triple phosphate of soda and ammonia, formerly called microcosmic salt, with the occasional use of the nitrate of cobalt, we can readily ascertain the presence of silica, alumina, magnesia, and almost all the fixed metallic oxides; and by the farther examination of the fused globule, especially that with carbonate of soda, by dissolving it in a drop of muriatic or nitric acid, on a slip of glass, and applying the proper tests, unequivocal evidence may be obtained of the presence of any of the other earths or oxides of which the substance is composed, and even a tolerable estimate may frequently be formed of their respective proportions.

By substituting nitrate of barytes as the flux, and using a slip of platinum foil for the support, instead of the wire, the presence of either of the alkalies may, by the well known processes, be detected with equal ease and certainty, on the same minute scale of operation.

An advantage peculiar to this microscopic chemistry is the very small quantity of matter that is sufficient for examination, which may generally be detached from rare and costly specimens without injury; whereas, for operations on a larger scale, it is necessary, wholly or in great measure, to destroy them.

When the exact proportions of the ingredients of a mineral are required, recourse must necessarily be had to more elaborate processes. But, even then, previous examination by the blow-pipe is of essential service, since, by indicating the different substances present, it enables us to determine the most advantageous method to be adopted in the subsequent operations.

To acquire the proper command of the instrument, which requires considerable practice, the best method is to keep as large a button as possible of tin melted upon the charcoal, and to bring it to a white heat, still retaining its metallic appearance. Tin is so easily calcined that, as soon as the propelled flame acquires an oxidizing quality, an infusible crust of oxide will cover the button. To prevent this oxidizement the beak of the blow-pipe must be very fine and not pushed too far into the flame of the lamp; which also must not have a long wick, as that would produce a smoking flame, soil the button, and diminish the heat.

FIRE-PLACES OR FURNACES FOR HEATING ROOMS.

There is another class of furnaces, not usually considered in books on chemistry, but which is, nevertheless, of great importance, namely, those which are used to heat the apartments in our dwelling-houses, our work-shops, and our repositories for foreign plants.

Rumford Stoves.

The great fault of all the open fire-places for burning wood or coals, now in common use, as Count Rumford very justly observes, is, that they are much too large; or, rather, it is the throat of the chimney, or the lower part of its open canal, in the neighbourhood of the mantel, and immediately over the fire, which is too large. This opening has hitherto been left larger than otherwise it probably would have been made, in order to give a passage to the chimney-sweeper.

As the immoderate size of the throats of chimneys is the great fault of their construction, it is this fault which ought always to be first attended to in every attempt which is made to improve them.

As the smoke and vapour which ascend from burning fuel, rise in consequence of their being rarefied by heat, and made lighter than the air of the surrounding atmosphere; it is clear the nearer the throat of a chimney is to the fire, the stronger will be what is called its draught, and the less danger there will be of its smoking. But, on the other hand, when the draught of a chimney is very strong, and particularly when this strong draught is occasioned by the throat of the chimney being very near the fire, it may so happen that the draught of air into the fire may become so strong, as to cause the fuel to be consumed too rapidly.

Nothing can be more perfectly void of common sense, and wasteful and slovenly at the same time, than the manner in which chimney-fires, and particularly where coals are burned, are commonly managed. Servants throw on a load of coals at once, through which the flame is hours in making its way, and frequently it is not without much trouble that the fire is prevented from going quite out. During this time no heat is communicated to the room; and what is still worse, the throat of the chimney being occupied merely by a heavy dense vapour, not possessed of any considerable degree of heat, it happens not unfrequently, that the current of warm air from the room which presses into the chimney crossing upon the current of heavy smoke which rises slowly from the fire, obstructs it in its ascent, and beats it back into the room. Hence it is that chim-

reservoir for the r[illegible]e a quantity of fresh coals is
tuse angle on the [illegible]s should never be put upon the
that the body o[illegible]ce passage of the flame between
flame. [illegible]n is paid to the quantity of coals
The best g[illegible]tle use for the poker; and this cir-
pipe is char[illegible]rery much to cleanliness, and to the
small bars;
better that [illegible]n examination, that the best form for the
The blo[illegible]hamber of a fire-place, or the covings, as
convenier[illegible]that of an upright plane, making an angle
that has [illegible]the back of the fire-place, of about 135 de-
nutes, t[illegible]g to the present construction of chimneys, this
examir[illegible]degrees, or forms a right angle; but as in this
rectir[illegible]des or covings, of the fire-place, *a*, *b*, *c*, *d*, Fig.
abou[illegible]l to each other, it is evident that they are very ill
hoo[illegible]for throwing into the room, by reflection, the rays
set[illegible]which fall on them.
c[illegible]fire
As bodies which absorb radiant heat are necessarily heated in
consequence of that absorption, to discover which of the vari-
ous materials that can be employed for constructing fire-places
are best adapted for that purpose, we have only to find out, by
an experiment very easy to be made, what bodies acquire least
heat when exposed to the direct rays of a clear fire;—for those
which are least heated, evidently absorb the least, and conse-
quently reflect the most radiant heat. And hence, it appears
that iron, and, in general, metals of all kinds, which are well
known to grow very hot when exposed to the rays projected by
burning fuel, are to be reckoned among the very worst mate-
rials that it is possible to employ in the construction of fire-
places. The best materials are fire-stone, and common bricks
and mortar.

When bricks are used they should either be covered with a thin coating of plaster, which, when it is become completely dry, should be white-washed, or the covings should be lined with white Dutch tiles, or marble. The fire-stone should likewise be white-washed when it is used; and every part of the fire-place which is not exposed to be soiled and made black by the smoke, should be kept as white and as clean as possible. As white reflects more heat as well as more light than any other colour, it is aways to be preferred for the inside of a chimney-fire-place: and black, so commonly used, which reflects neither light nor heat, should be avoided. How much inferior, also, in liveliness, is the dingy black chimney of the present day, to the bright stove-grate, and white chimney of forty years ago, before the introduction of the Bath stoves.

There is, however, in chimney fire-places destined for burning coals, one essential part; the grate, which cannot well be

ıe of any thing else but iron; but there is no necessity whatever for that immense quantity of iron which surrounds grates as they are now commonly constructed and fitted up, and which not only renders them very expensive, but injures very essentially the fire-place.

Registers also are not only quite unnecessary, where the throat of the chimney is properly constructed, and of proper dimensions, but in that case would do much harm. Without doubt registers have often been found to be of use; but it is because the great fault of all fire-places constructed upon the common principles, being the enormous dimensions of the throat of the chimney, this fault has in some measure been corrected by them; but there never was a fire-place so corrected that would not have been much more improved, and at infinitely less expense by the alterations hereafter recommended.

The bringing forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminishing of the throat of the chimney, being the two objects principally held in view in the alterations in fire-places recommended, it is evident that both these may be attained merely by bringing forward the back of the chimney as far as possible, without diminishing too much the passage which must be left for the smoke.

The back of the chimney must always be built perfectly upright: to determine therefore the place for the new back, or how far precisely it ought to be brought forward, nothing more is necessary than to ascertain how wide the throat of the chimney ought to be left.

[The direction to build the back of the chimney perfectly upright is objectionable, as will be seen on the two following pages; a jutting back from the top of the fuel when the grate is full to within three or four inches of a line corresponding with the lower edge of the mantelpiece is found to be far preferable, on account of the more favourable position of the surface for the reflection of the radiant heat into the room.]

It has been found that when the back of the fire-place is of a proper breadth, the best depth for the throat of a chimney from front to back, when the chimney and the fire-place are of the usual form and size, is four inches, and this whether the fire-place be destined to burn wood, coals, turf, or any other fuel commonly used for heating rooms by an open fire, and whatever may be its width.

Provision must be however made, at least in London, for the passage of the chimney sweeper up the chimney. This may easily be done in the following manner;—In building up the new back of the fire-place, when this wall, which

need never be more than the width of a single brick in thickness, is brought up so high that there remains no more than about ten or eleven inches between what is then the top of it, and the inside of the mantel, or lower extremity of the breast of the chimney, an opening, or door-way, eleven or twelve inches wide, must be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be necessary to carry up the back, will make the opening about twelve or fourteen inches high, which will be quite sufficient to allow the chimney-sweeper to pass. When the fire-place is finished, this door-way is to be closed by a tile, or a fit piece of stone placed in it, dry, or without mortar, and confined in its place by means of a rabbit made for that purpose in the brick-work. As often as the chimney is swept, the chimney-sweeper takes down this tile, which is very easily done, and when he has finished his work, he puts it again into its place.

The current of air which, passing under the mantel, gets into the chimney, should be made gradually to bend its course upwards, by which means it will unite quietly with the ascending current of smoke, and will be less likely to check it or force it back into the room. This may be effected with the greatest ease and certainty, merely by rounding off the breast of the chimney, or back part of the mantel, instead of leaving it flat, or full of holes and corners.

As many of the grates now in common use will be found to be too large, when the fire-places are altered and improved, it will be necessary to diminish their capacities by filling them up at the back and sides with pieces of fire-stone.

The proper depth from front to back for grates destined for rooms of a middling size will be from six to eight inches, and their lengths may be diminished more or less, according as the room is heated with more or less difficulty, or as the weather is more or less severe. But where the depth of a grate is not more than five inches, it will be very difficult to prevent the fire from going out

Where it is necessary that the fire in a grate should be very small, it will be proper, in reducing the grate with fire-stone, to bring its cavity, destined for containing the fuel, to the form of one-half of a hollow hemisphere; the two semicircular openings being one above to receive the coals, and the other in front, resting against the bars of the grate; for when the coals are burnt in such a confined space, and surrounded on all sides, except in the front and above, by fire-stone, which is a substance peculiarly well adapted for confining heat, the heat of the fire will be concentrated, and the cold air of the atmosphere being kept at a distance, a much smaller quantity of coals will burn than could possibly be made to burn in an iron grate.

Where grates which are destined for rooms of a middling size, are longer than fourteen or fifteen inches, it will always be best, not merely to diminish their lengths by filling them up at their two ends with fire-stone, but after forming the back of the chimney of a proper width, without paying any regard to the length of the grate, to carry the covings through the two ends of the grate in such a manner as to conceal them, or at least to conceal the back corners of them in the walls of the covings.

Fig. 41, shows how the fire-place is to be altered in order to its being improved.

a b, is the opening in front; *c d*, the back; and *a c* and *b d*, the covings of the fire-place in its original state.

a b, its opening in front; *i k*, its back; and *a i* and *b k*, its covings after it has been altered; *e*, is a point upon the hearth upon which a plumb suspended from the middle of the upper part of the breast of the chimney falls. The situation for the new back is ascertained by taking the line *e f*, equal to four inches.

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Fig. 41.

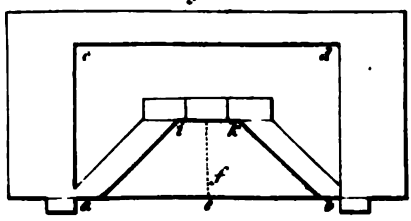


Fig. 42.

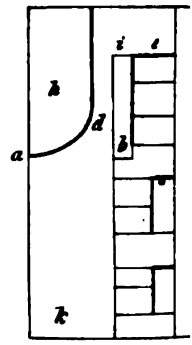


Fig. 43.

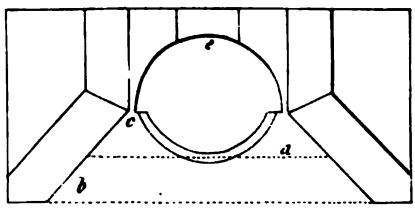


Fig. 45.

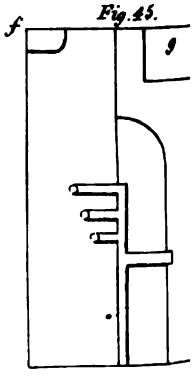


Fig. 44.

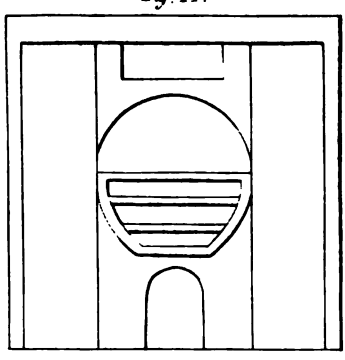


Fig. 46.

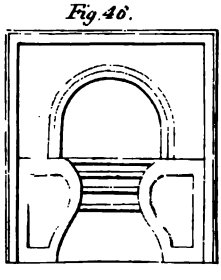
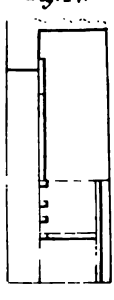


Fig. 47.



The new backs and covings are represented as being built of bricks; and the space between these and the old back and covings as being filled up with rubbish.

Fig. 42, shows a section of a chimney after it has been altered; *k l*, is the new back of the fire-place; *b i*, the tile or stone which closes the door-way for the chimney-sweeper; *d i*, the throat of the chimney narrowed to four inches; *e*, the mantel; and *h*, the new wall made under the mantel to diminish the height of the opening of the fire-place in front.

In general it will be best, not only for the sake of the appearance of the chimney, but for other reasons also, to lower the height of the opening of the fire-place whenever its width in front is diminished.

When the wall of the chimney in front, measured from the upper part of the breast of the chimney to the front of the mantel, is very thin, it may happen that the depth of the chimney may be too small. In this case the depth of the fire-place at the hearth should be increased twelve or thirteen inches, and the back built perpendicular to the height of the top of the burning fuel.

Then sloping the back by a gentle inclination forward, bring it to its proper place, that is to say, perpendicularly under the back part of the throat of the chimney. This slope, which will bring the back forward four or five inches, or just as much as the depth of the fire-place is increased, though it should not be too abrupt, yet it ought to be quite finished at the height of eight or ten inches above the fire, otherwise it may perhaps cause the chimney to smoke; but when it is very near the fire, the heat of the fire will enable the current of rising smoke to overcome the obstacle which this slope will oppose to its ascent, which it would not do so easily were the slope situated at a greater distance from the burning fuel.

A fire-place having been carried back in the manner here described, in order to accommodate it to a chimney whose walls in front were remarkably thin, it was found on lighting the fire that it appeared to give out more heat into the room than had ever been witnessed. This effect was unexpected; but the cause of it was too obvious not to be immediately discovered. The flame rising from the fire broke against the part of the back which sloped forward over the fire, and this part of the back being soon very much heated, and in consequence of its being very hot, indeed, when the fire burnt bright it was frequently quite red hot, it threw off into the room a great deal of radiant heat. It is not possible that this oblique surface, namely, the slope of the back of the fire-place could have been heated red hot merely by the radiant heat projected by the burning fuel, for other parts of the fire-place nearer the fire, and better situated for receiving radiant heat, were never found to be so much heated; and hence it appears that the combined heat in the current of smoke and hot vapour which rises from an open fire may be at least, in part, stopped in its passage up the chimney, changed into radiant heat, and afterwards thrown into the room.

Figs. 43, 44, 45, show a plan, elevation, and section of a fire-place constructed or altered upon this principle.

The wall of the chimney in front, *a*, fig. 69, being only four inches thick, four inches more added to it for the width of the throat would have left the depth of the fire-place measured upon the hearth, *b c*, only eight inches, which would have been too little; a niche, *c* and *c*, was therefore made in the new back of the fire-place for receiving the grate, which niche was six inches deep in

the centre of it below, thirteen inches wide, or equal in width to the grate, and twenty-three inches high; finishing above with a semicircular arch, which in its highest part, rose seven inches above the upper part of the grate. The door-way for the chimney-sweeper, which begins just above the top of the niche, may be seen distinctly in both the figures, 70 and 71. The space marked, *g*, fig. 71, behind this door-way, may either be filled with loose bricks, or may be left void. The manner in which the piece of stone, *f*, fig. 71, which is put under the mantel of the chimney to reduce the height of the opening of the fire-place, is rounded off on the inside, in order to give a fair run to the column of smoke in its ascent through the throat of the chimney, is clearly expressed in this figure.

These improvements of our ordinary stoves, proposed by Count Rumford, have been very generally adopted in London, and few fire-places are to be seen in a sitting-room which has not been Rumfordised: but in most cases the form alone of the improvement has been seized, and the most essential points neglected, to please the eye. The sides and back of grates are still made of iron, the side-fronts, hobbs, and covings, are of the same so highly improper material, and covered with a black lugubrious coating, instead of being lined with white Dutch-tiles as formerly, or the large cream yellow earthen-ware-tiles used for paving in some parts of Wales; either of which could be washed clean with a little soap and water: in elegant rooms the covings might be made of white, or rather yellow marble, which is most agreeable to the eye.

Mr. Tredgold is of opinion that the grates of open fire-places ought to be one-twelfth the length of the room; and if this is more than thirty feet in length, two fire-places will be requisite. The depth from front to back cannot be less than six inches; and if the breadth of the room exceeds twelve feet, an additional half inch may be added to the depth for each additional foot of breadth in the room.

The round lumps of baked clay, or fire-balls, sometimes put into the fires of common grates, to diminish their intensity, are extremely troublesome to manage, and the fire soon goes out, if it be not carefully minded: hence they are worse than useless. They must not be confounded with the fire-balls to be used as fuel, especially as there is reason to think that their being called by the same name, has tended to prevent the introduction of the latter.

Irish Stoves.

Mr. Buchanan, in his Essay on the Economy of Fuel, relates, that on landing in Ireland, he was struck with the excellent construction of the fire-grate in his room at the inn where he lodged. He at first thought it was an invention of his landlord's, but on proceeding on his journey, he found

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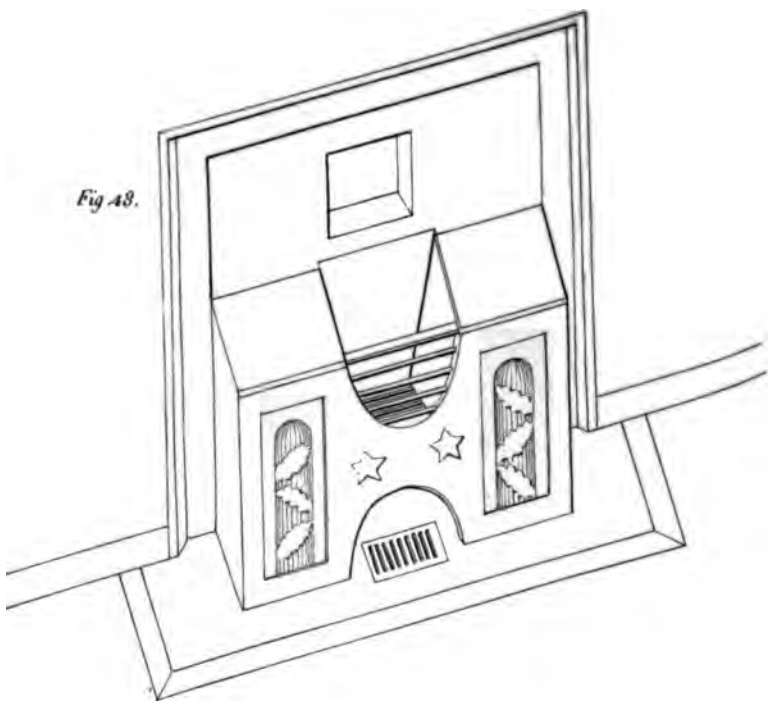
TILDEN FOUNDATIONS

Fig 48.



these kind of fire-grates very common in that part of Ireland.

Figs. 46 and 47, represent the one a front view, and the other a transverse section from front to back of these fire-places, which appear well calculated to remedy the smoking of chimneys, and, at the same time, to lessen the consumption of fuel. The fire-room is wide and shallow, in order to present the greater surface of fire to the room, that by its radiation it may throw out the greatest possible quantity of heat. The upper portion of the chimney recess is partly closed by an upright slab of fire-stone, in which is cut an arch. The back wall is formed of fire-stone, or fire-brick, into an oval niche, and the throat of the chimney is made very small, to increase the velocity of the air, and thus enable it the better to carry off the smoke.

Staffordshire Stoves.

Somewhat similar to this is the usual manner of setting grates in the sitting-rooms in Birmingham and its neighbourhood.

Fig. 48, represents this mode of setting grates. The usual recess built in rooms for the insertion of whatever grate or stove the occupier may bring in, is built up by a wall in front even with the mantel-piece; and only a small opening is left for the passage of smoke into the chimney, just above the back of the grate, which is placed against this wall, and projects entirely into the room.

The dimensions of the opening for the passage of smoke varies but slightly according to the size of the grate, and is usually about nine inches square.

If the recess of the chimney is very large, as when the kitchen of an old house is converted into a sitting-room, or the occupier is desirous of practising economy, a flue is built up at the back to meet the throat of the old chimney; the new grate is placed against this flue, and the sides of the old recess serve as open closets for things that require slow drying, or being kept dry and warm.

These methods of setting stoves in open fire-places, may certainly be considered superior to that of the American chemist, Count Rumford, originally Mr. Benjamin Thompson.

There is, from long custom, so great a desire amongst all ranks in England, to see the fire which warms their apartments, that the most convenient, cleanest, and cheapest methods of heating them are sacrificed to this single circumstance. Yet, no one who has considered the subject, can have the slightest hesitation in saying, that heating apartments, either by close stoves, ovens, or steam-pipes, which radiate heat from their sides, or by a current of warm air, heated in the lower part of the house and ascending to the upper apartments, is far preferable, if the necessary attention is paid to cleanliness, to the rude and unphilosophic method of heating rooms by open fire-places.

The currents of air in rooms heated by the ordinary open fire-places, are frequently a complete nuisance; and independent of these currents, as the occupiers of the room are always between the fire-place and the source from whence the air comes, it is impossible to preserve an equality of temperature throughout our whole frame, as sometimes even one part of the body is roasting, while the other parts are freezing.

Not but that it is certainly an overstrained idea of comfort to suppose an absolute equality of heat in our apartments desirable. This equality does not exist in nature; the sun warms us by radiant heat, and, consequently unequally; we never feel heat oppressive nor injurious till the air becomes hot; and if there be an inconvenience in that inequality of heat, which we must be sensible has place every time the sun shines, it is an inconvenience that has never been felt; the cool freshness of the air, and the warmth of the sun's rays, are sensations most pleasurable when united. Plants, in the natural state, are also exposed to this inequality of temperature: those who have cultivated them with most success, have found that uniform heat is not desirable, when it is applied artificially. An imitation of nature in treating plants, has been attended with sufficient advantage to show that it is the proper course to be followed.

[*American Grates for Burning Anthracite Coals.*

The greater difficulty of burning the anthracite coals, now extensively used in our Atlantic cities, has suggested an alteration in the construction of the common grates, which is so simple, and so decidedly preferable to the usual form, that it is not a little remarkable that it has never before been adopted; it consists in placing the front bars of the grate in a vertical, instead of a horizontal position; the bars at the bottom of the grate run in the usual direction, (i. e. from front to back,) and are merely continuations of the vertical part bent at right angles at the bottom, and front of the fire-place. This arrangement is much more favourable for the admission of air to the burning fuel than the common method; indeed it has been found nearly impossible to burn the anthracite coals in the usual English grates. The construction of stoves and grates for the combustion of this fuel has become an object of such great practical importance, that I cannot refrain from quoting the following judicious remarks from Mr. Bull's "*experiments to determine the comparative loss of heat sustained by different constructions of apparatus ordinarily used for the combustion of fuel.*]

"The difficulty of consuming small quantities of anthracite coal in open grates, must operate to prevent its general introduction into use, unless this difficulty can be removed; any suggestions, therefore, which may possibly tend to lessen this objection to an article of such vast importance to the community, will not be considered irrelevant to my subject.

"It is very well known, that no particular difficulty is experienced, under ordinary circumstances, in consuming small quantities of this coal in sheet iron cylinder stoves lined with

fire-brick, and it is as well known, that an equally small quantity of this coal cannot be consumed in an open grate. The inference, therefore, which should be drawn from the knowledge of these facts, is, that the open grate is an apparatus not properly constructed to obtain the desired object, independent of the deleterious gas which it imparts to the room. The question which then presents itself, is, what are the qualities possessed by the former apparatus in which the latter is deficient?

"In the former, the coal is known to be completely surrounded by a thick substance, which, when heated, retains its heat with great tenacity. The air admitted is in small quantity, and, from the construction of the stove, it is necessarily considerably elevated in its temperature, before it comes in contact with the burning body. We infer from these facts, that anthracite coal requires a very high temperature to produce ignition, and, as we know that combustion cannot take place without this prerequisite, the necessary means to effect it, are, consequently, indispensable. We also infer, that the commonly received opinion, that this coal requires a very large quantity of air, or "strong draught," to carry on its combustion, is not correct; the converse of this opinion being nearer the truth; and this may in part be demonstrated by an examination of a single piece of this coal which has been ignited. If we break the piece of coal, the interior will present its original black colour and lustre, with the exception of an inconsiderable portion near the surface; the body of the coal being sufficiently dense to exclude the access of air, no cumbustion of its interior can take place, and, consequently, the quantity of air necessary to be admitted to the coals, is nearly proportional to *their surfaces*, but not in proportion to their positive quantity, as would be nearer the case, if this article were as pervious to air as charcoal. Any excess of air, therefore, is injurious in proportion as the quantity exceeds that which can unite with what is termed the combustible or base, inasmuch as it tends to reduce its temperature, and thereby renders it less capable of rapid union with the air, to produce the combustion; and as each successive portion of air in excess robs the combustible of its heat, we see the fire languish for a short period, and then expire.

"Although atmospheric air is generally necessary to support combustion, an excess of it, it is well known, will, in some cases, extinguish a burning body, as expeditiously as water; and from this circumstance it may be inferred, that for ignition, the air requires to be heated as well as the combustible body. We may also infer, that the intensity of heat produced by the union of the two bodies will be proportional to the excess with which their united heats exceed their mean heat of ignition.

"Having had occasion, during the past winter, to warm two warehouses, of different sizes, and it being necessary that the temperature should be permanent during the night season, two cylinder sheet iron stoves of ordinary construction, and of different sizes, lined with fire-brick, were procured, which were supplied with Lehigh coal.

"The construction of the stoves being favourable to apply on a large scale what I had found so advantageous in my expeririment stove, there being considerable space between the grate and the bottom of the ash-pan, this space was converted into a reservoir for heating the air, by closing the apertures usually made for its admission in the front of the ash-pan. During the igniting process, the ash-pan was drawn out, but when this was effected, it was closed as perfectly as its construction would admit, leaving only the small crevices at its junction with the body of the stove for the admission of air, and although the largest stove usually contained more than half a bushel of coal, this supply of air was found sufficient for producing intense combustion, and the quantity of coal remaining on the grate unconsumed, was found to be much less than when the stove was supplied with a larger quantity of air; a very important saving was thus made in the heat, by diminishing the quantity and the velocity with which the current of heated air passed into the chimney. Very important improvements may be made in the construction of sheet iron stoves, for burning anthracite coal; and, if provision is made for supplying the burning body with *intensely heated air*, any required quantity of coal may be consumed, and the present manner of lining them with thick brick may be entirely dispensed with, by substituting either thin tiles, or a thin coating of clay lute, sufficient to preserve the iron from fusion or oxidation, and, as this would present less obstruction to the speedy communication of the heat generated to the air of the room, consequently less would escape into the chimney.

"In examining the construction of the open parlour grate, we do not find in it one entire quality possessed by the close stove: the only one which bears any approach to similarity, is, that three sides of the grate are lined with fire-brick; but, as the fourth is almost wholly exposed, its utility is thereby defeated.

"It is admitted that the combustion is very perfect and rapid, when the sheet iron door, or "*blower*," as it is technically termed, is applied to close the front of the grate; and this must be a necessary consequence, as its application transforms the open grate into a powerful *air furnace*, by which the space for the admission of air is very much reduced, and the air is probably reduced in quantity, this not being compensated by its increased velocity, and as the blower defends the body of coal

in front from the cold air, to which it was before exposed, the required elevation in temperature is effected and maintained without difficulty.

"It is only by radiation that any heat is imparted to the room from coal consumed in open grates, and as the radiated heat is known to be very small from the surface of that portion of coal which is exposed to the front or open part of the grate; the amount of heat imparted to the room would not probably be diminished, but rather increased, by using a thin plate of cast iron for the front of the grate, by which the difficulty of consuming small quantities of coal would be very much diminished; and this would not be less agreeable in its appearance than the equally *sombre* aspect presented by the unignited coal in the front of the generality of small grates, and particularly as the top of the coal would be exposed to view, and present a more luminous appearance.

"Although iron is a good conductor of heat, the plate suggested would become sufficiently heated to maintain the temperature of the coal necessary to carry on the combustion of the surface exposed to it, with the exception of the points actually in contact with it, which would be unimportant; and this being the case, its conducting power would, in other respects, be obviously advantageous, and no danger of melting the iron, in this situation, need be apprehended. If, however, danger from melting or oxidation of the iron is feared, as a flat plate of iron could not be permanently covered with any composition of clay, it should be made circular, and defended at the top and bottom by a flange projecting on the inside, the required thickness of the clay. In addition to the plate suggested to cover the front of the grate, a still farther improvement might be made by enclosing the ash pit also, both of which might be done with one plate of iron, and the grate for sustaining the coal might rest upon cleats projecting from the interior, taking care to give sufficient room for the expansion of the grate, to prevent the plate being pressed outwards. A door for the removal of ashes and the admission of air would be required, by which the necessary quantity of air could be admitted without an excess. This construction would also be favourable for heating the air which is to supply the combustible body, the advantage of which must be obvious, when we reflect on the necessity of cooling the burning body as little as possible. By the greater expansion of the air, the quantity which comes in contact with the burning body would be less in excess, at any one time, and better adapted to attain the object; the contact being more frequent, from its increased velocity, the quantity actually united in any given time, would probably be greater, and more heat would consequently be pro-

duced. This construction, besides the advantages already stated, would be more cleanly than the open grate, would not require the blower, and could also be made use of for culinary purposes, which is a very desirable object to be attained.

"The construction of many grates is very objectionable, in an important particular not yet noticed, which is, making the receptacle for the coal of greater length than it has breadth or depth, by which the body of coal is not as much heated, and requires to be replenished more frequently to maintain the relative position of the coal, necessary to continue the combustion. A much better shape, and which would require less coal at any one time, would be in the proportions of twelve inches deep, to eight inches square at the top, and gradually diminished to six inches at the bottom, by which the heat generated in the combustion of the coal at the lower part of the grate, in its passage to escape into the chimney, would come in contact with nearly the whole body of coal, and keep it heated, which cannot be the case in the former shape, supposing the contents of the two grates, and the coal in each to be equal; and if we suppose them to be only *half filled* with coal, the position of that in the deep grate, although less in quantity, will be very favourable for combustion, while that in the shallow grate, from the unfavourable situation in which it is placed, would scarcely burn at all. The advantage of placing the body of coal in a deep grate, as described, may be illustrated by the well known fact, that a stick of wood burns much more rapidly in a vertical, than in a horizontal position, and for the reason already assigned.

"Being well aware of the strong predilection in favour of those constructions which will permit the burning body to be seen, which, with other reasons prevents the use of close stoves in many instances, and particularly where elegance is required, the necessity is apparent, that some new construction should be devised, which can be substituted for the open grate, and which will obviate the difficulty, not only of consuming anthracite coal in small quantities, for rooms of small dimensions, but, the still greater objection generally made to its use, that the quantity cannot be varied to meet the changes in the temperature of the atmosphere.

"In the plan which I will venture to suggest, a partial compromise must be made in the first particular stated, but all the others may be realized.

"In those instances where simplicity of construction is required, take a cylinder, or, rather, an inverted conical frustrum, of cast iron, of any required thickness and diameter, and of sufficient height to form the receptacle for the coal and ashes; insert a grate at a sufficient height from the bottom to leave the

required room for the ash pit, which should be provided with a door to remove the ashes and unconsumed coal, as is usual in close stoves, and, also, to regulate the admission of air, which may be heated as in those stoves. This cylinder may be bricked in the ordinary manner on the outside; and this can be done with greater facility than for the grate, and the cylinder will remain more permanently fixed, as it will rest on the hearth. From the satisfactory experiments which have been made in double cylinder stoves, in which the interior cylinder is made of cast iron, without any coating of clay, it is not probable that this construction would require it. In those instances in which beauty of construction must be consulted, the ornamental parts or appendages to the open grate may be added; the only change suggested being the substitution of a cylinder, or other more desirable shape, of cast iron, in place of the open grate."

[*American Fire-Places for Burning Wood.*

The hearth is on a plane with the floor of the room, in which the fire-place is situated; the jambs, or vertical sides of the fire-place, should form an angle with the back of 135°; the back wall should rise perpendicularly one-half the distance from the hearth to a line on a plane with the lower edge of the mantel-piece, and then form such an inclination forward as shall bring it within four inches of the mantel when it has attained to that height, where it terminates; the mantel-piece should be smooth on its inner and back surface, and form a segment of a circle from its lower and front edge to the uppermost posterior edge. The dimensions of the fire-place must vary with the size of the apartment to be warmed; one whose mantel shall span 41 inches from jamb to jamb in front, and whose depth from back to front on the hearth shall be 12 inches, and height from hearth to mantel 33 inches, will warm a room twenty feet square and ten feet high, or four thousand cubic feet of air. A fire-place of this construction embraces all the valuable improvements of Count Rumford and Dr. Franklin: its surfaces are so disposed as to be highly favourable for the reflection of the radiant heat, by which our apartments are principally warmed by open fire-places of almost every description; the rays of caloric, which emanate from the burning fuel, impinge upon the jambs and back, at such an angle as to be reflected into the room. Owing to the height of the mantel-piece, the great extent of surface, as well as the position of the back and jambs is favourable also to the radiation of that portion of heat, which is absorbed by them. The parts, which are exposed to a temperature approaching a red heat and above, should be constituted of brick, or soap-stone; but the front of the jambs and the mantel-piece may be

formed of free-stone, or marble, at the pleasure of the architect. The lighter the colour and the more polish there is upon the jambs the more of the radiant heat will be reflected, and the less absorbed in the first instance.

American Double Fire-Place.

A recent improvement upon the Rumford plan is what has been called the double fire-place. To understand its construction it is only necessary to suppose a fire-place of the same form and dimensions as the one last described, set within another of sufficient size to receive it and leave an open space between the hearths and walls of each of from 1 to 1½ inches in width; some builders make the mantel-piece hollow, also; in which case the included space communicates with the one between the walls. This enclosure has two openings, one communicating with the external air through the back of the chimney, or through an iron pipe laid for that purpose, of from 1 to 2 inches diameter, and the other with the air of the room at the side of the chimney a little above the mantel. The interior or smaller fire-place is constructed of slabs of soap-stone, of from 1½ to 2 inches in thickness, accurately jointed and fitted together. The advantages proposed by this construction over the common Rumford fire-place are two-fold;—first, to secure a ventilation of the room by fresh warm air, and secondly to save that heat, which in the usual construction is absorbed by the walls, and lost by slow communication through the back of the chimney. These objects are certainly secured, but the construction of these fire-places is attended with considerable additional expense; they are more liable to fall out of repair, and their use will probably, for the most part, be confined to the apartments of the rich.

Much has been said and written concerning the great waste of fuel, in even the best constructed fire-places, when compared with other methods of warming our apartments. Dr. Franklin estimated that in the deep low fire-places in use in his day, ninety-five *per cent.* of the heat generated by the combustion of the fuel escaped up the chimney, and was lost. Mr. Bull, in his recent experiments, estimates the loss in a fire-place of "ordinary construction," (by which I understand a fire-place on the Rumford plan,) at ninety *per cent.* The following table contains the results of Mr. Bull's experiments on the combustion of perfectly dry wood in five of the most usual forms of apparatus in use. I extract it by permission from his interesting paper, from which I have already quoted largely in different parts of this work.

Table exhibiting the results of experiments made to determine the comparative loss of heat sustained by using apparatus of different constructions, for the combustion of fuel.

Description of apparatus used.	Time the room was maintained at the same temperature, in the combustion of equal weights of fuel, compared with apparatus No. 9.	Weight of fuel required by each apparatus, to maintain the room at the same temperature, and for the same time, compared with No. 9.
No. 1. CHIMNEY FIRE-PLACE, of ordinary construction, for burning wood, . .	10	1000
2. OPEN PARLOUR GRATE, of ordinary construction, for burning anthracite coal, ...	18	555
3. OPEN FRANKLIN STOVE, with one elbow-joint, and 5 feet of six inch pipe placed vertically, the fire-place being closed with a fire-board, ...	37	270
4. CAST IRON TEN PLATE STOVE, with one elbow-joint, and five feet of four inch pipe, placed horizontally, entering the fire-board, ...	45	222
5. SHEET IRON CYLINDER STOVE, the interior surface coated with clay lute, with one elbow-joint, and 5 feet of two inch pipe, placed horizontally, entering the fire-board, ...	67	149
6. SHEET IRON CYLINDER STOVE, as before described, with 13½ feet of two inch pipe, in which there were 3 elbow joints, the whole placed as follows: 3½ feet horizontally, 5 feet vertically, for an ascending current, and 5 feet vertically, for a descending current, entering the fire-board, ...	78	128
7. SHEET IRON CYLINDER STOVE, as before described, with 13½ feet of two inch pipe, in which there were 3 elbow-joints, placed as follows: nine inches vertically, and 12¾ feet horizontally, entering the fire-board, ...	82	122
8. SHEET IRON CYLINDER STOVE, as before described, with nine elbow-joints, measuring 13½ feet of two inch pipe, entering the fire-board, . .	95	105
9. SHEET IRON CYLINDER STOVE, as before described, with 42 feet of two inch pipe, as used in the course of experiments on fuel, ...	100	100

It will be perceived, that, in the above table, Mr. Bull proceeds on the assumption, that in No. 9 (which was the same stove as used by him in his experiments to determine the comparative heat produced by the combustion of equal weights of the principal varieties of fuel in the United States) there is an entire saving in the apartment of the heat produced in the combustion. The arrangement, indeed, affords as near an approximation to such a result as is possible to conceive of obtaining by any means whatever, unless it be by burning the fuel in the open room without the use of a chimney; for, a thermometer, the bulb of which was inserted into the pipe just before it entered the chimney, indicated the same temperature as one which was suspended in the room without the pipe, at the same elevation from the floor: no portion of the sensible heat, therefore, was lost by the flue, except that part which was contained in the air which supported the combustion. The results in the first column were obtained by actual experiment, and those of the second column by common proportion.

The effect of position, and increasing the number of elbows or turns in the pipe, is strikingly shown in Nos. 6, 7, and 8, in which the stove, the length of the pipe, and every other circumstance are the same. These effects are reasonably attributed, by Mr. Bull, to the retardation, and the sudden and abrupt changes of the currents of heated fluid in the pipe, by which the relative position of the different portions are more frequently changed, and the hotter particles of the interior of the current are brought successively to the surface, and, after imparting their heat to the pipe, give place in their turn to others.

If the attainment of a given temperature in our apartments, at the least expense of fuel, were to be the only circumstance in determining our choice of one of the usual means of effecting that object, no one could hesitate for a moment to adopt the close stove, with a sufficient length of tortuous pipe. But the open fire-place, though far more wasteful of fuel, possesses compensating advantages, which always have, and always will render it a favourite in our parlours:—the cheapness and simplicity of its construction, the perfect ventilation which it affords the apartment, the cheerfulness produced by the sight of the fire, and the comforts of a warm hearth, are circumstances which strongly recommend it. The difference in the expense of supplying the open fire-place and the close stove is by no means so great in actual practice as we should infer from experiment; for people are generally willing to accept, and do, in fact, cheerfully submit, to a much lower temperature in their apartments in the use of the former than they will do with the latter. The practical advantage derivable from warm feet will, in the minds of many, more than compensate for the difference in the expense of fuel necessary to supply each.

The open parlour stove, with a short flue, is an apparatus possessing properties intermediate between the close stove and open fire-place, both in respect to economy of fuel, and pleasantness in use.]

Close Stoves.

There is yet another mode of distributing heat, which has the advantage of preventing the air being in contact with a surface heated above 212 degrees. It consists in confining the burning fuel within a proper thickness of matter, generally of a slow conducting power. The material usually employed is brick, or fire-stone; and the flues of hot-houses have always been formed in this manner, whether from principle or convenience it is difficult to ascertain. The extent to which heat can be carried by this method is very limited; but if the materials are unexceptionable, it is much the best and most simple method of heating air on a small scale.

The various forms of close stoves, called Swedish, &c. are only variations of this method.

The use of them, in the northern parts of Europe, is indispensably necessary, as without them it would be impossible to keep their rooms warm. These stoves retain the heat a long time; and as their external parts, and also their flues, are very thin, they communicate their heat very readily, so that with a small quantity of wood, they warm an apartment much more than the fire of a common fire-place would do with six times the quantity.

[It is certainly a mistaken idea of the author, that close stoves fabricated of brick, stone, or pottery ware, can possess superior properties to iron ones of similar construction for conducting and diffusing heat; it is directly opposed to the best established facts in relation to the laws of caloric. Stoves, however, constructed of these materials, possess some advantages over those of iron; they afford a more equable and pleasant heat, owing to the inferior conducting power of their material, and its superior capacity for heat, apartments warmed by these stoves are not subject to those sudden alternations of temperature that iron ones occasion. When the temperature within is intense, their walls absorb and retain more heat, and impart it more gradually to the room when the fire burns low. Yet, by increasing the length and convolutions of the flue in an inverse ratio to the conducting power of the walls, when composed with iron, the same, or nearly the same, amount of heat may be obtained. These stoves are not subject to the unpleasant smell attendant on those constructed of iron, which is owing to the decomposition of minute particles of dust, and other matters, which come in contact with a surface of quick conducting power. A few years since brick stoves constructed on the Russian

plan, were very common in New England. Some popular writer, or circumstance, not now recollected, produced a strong sentiment in their favour, and almost every inn, and thousands of private dwellings, were furnished with one or more of them; but their popularity was short, and they have now fallen into very general disuse. The cause of this sudden revulsion of public opinion is to be attributed partly to the extravagant expectations, which were first formed of their utility, and partly to the very clumsy and imperfect manner in which they were frequently constructed. The one above described, appears well adapted for securing the peculiar advantages derivable from this method of house-warming.]

The stoves perfectly fulfil the above-mentioned intentions; they are also susceptible of every kind of ornament; and nothing can be handsomer than the stoves of pottery-ware that are to be seen in French Flanders, or the Russian stoves finished in stucco.

The more surface we give to a stove constructed in this manner, the more the heat is increased, consequently we must not be surprised to find that this kind of stove sometimes occupies the whole height of an apartment, its width and depth being proportioned to its height.

Fig. 49, represents one side of the stove: *a*, is the door by which fuel is introduced, and through which the fire is lighted. In this door there is usually a very small wicket shut by a slider.

Fig. 50, is a transverse section of the same stove, about one third of its length from the side in which the feeding-door is placed; *b*, is the cavity, in which the fuel is placed, and which may properly be called the fire-room. It is separated from the hollow space, *c*, left under the stove, by an earthen floor; *d*, are cavities which serve to collect and retain the heat, and also to form passages for the smoke; *e*, is another cavity which has no communication with the interior cavities, consequently affords no passage for the smoke: this cavity is formed in the highest part of the stove, and is used as a kind of pan in which to dry articles: but it collects dust, and a plain flat surface is far preferable for the top of these stoves.

The construction and the direction of the smoke will be better understood by considering fig. 51, which represents a section of the stove from side to side, about one-third of its depth from the front to the back.

H, shows the fire-place charged with wood, and the course of the smoke. The roofs, *k*, of the three uppermost cavities, are formed of earthen tiles. Two of these roofs do not reach quite across, but are continued only a little more than three quarters of the whole space, and are supported at their extremities, *l*, by pieces of iron fixed in the stove. By this means the smoke finds a free passage, and follows the current of the air.

The course of the smoke appears more clearly in fig. 52, being a transverse section of that part of the stove that is the farthest from the feeding-door. In this section, *m*, represents the flues for the smoke. On a level with the upper part of the cavity for the fuel or fire-place, and in the last of the flues, is fixed a trap, *n*, which is to be closed when the fuel is thoroughly red hot; by which means its farther combustion is prevented, and all the heat is confined in the stove, from which it spreads itself into the apartment. But, as when the air of the atmosphere is very cold, it would be apt to communicate a portion of its coldness to that which is near the valve, *n*, a second trap is placed in the exterior part of the chimney where it is carried up beyond the roof of the build-

Fig. 51

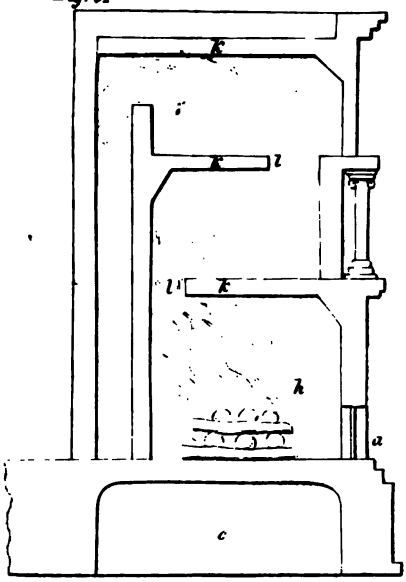


Fig. 52

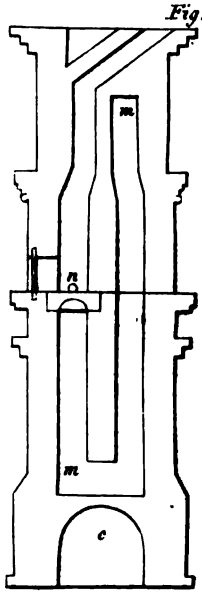


Fig. 49

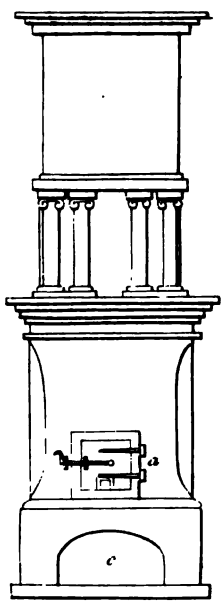
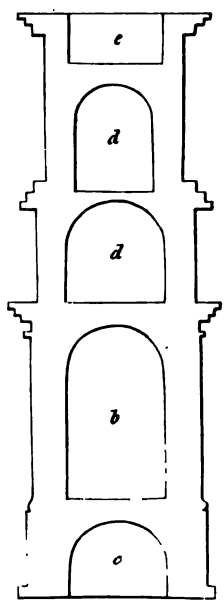
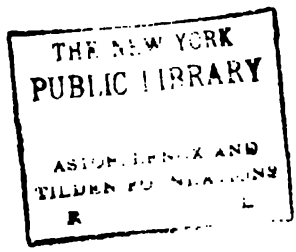


Fig. 50

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g. By means of an iron rod communicating with both valves, the operation opening and shutting them is rendered very quick and easy.

The more usual way, however, of shutting up this passage is by a sort of n or bowl of earthenware, which is whelmed over it with its brim resting in nd contained in a groove formed all round the hole. This damper is introuced by an opening in the front, which is then shut with a thick earthen opper. The whole is set on low pillars or arches, so that its bottom may be few inches from the floor. It is usually placed in a corner; and the apartents are so disposed that their chimneys can be joined in stacks as with us.

Some straw or wood shavings are first burnt on the hearth at s farther end. This warms the air in the stove, and creates a etermined current. The wood is then laid on the hearth close y the door, and piled up. It is now lighted, and the current eing already to the vent, there is no danger of any smoke oming out into the room. Effectually to prevent this, the oor, *a*, is shut, and the wicket opened. The air supplied by his being directed to the middle or bottom of the fuel, quickly indles it, and the operation goes on.

The aim of this construction is very obvious. The flame and eated air are retained as long as possible within the body of he stove by means of the long passages; and the breadth is neessary below, that there may be room for fuel. If this breadth vere preserved all the way up, much heat would be lost, because he heat communicated to the partitions of the stove does no good. By diminishing their breadth the proportion of useful surface s increased.

It is with the same view of making an extensive application of a hot surface to the air that the stove is not built in the wall, nor even in contact with it, nor with the floor; for by its detached situation the air in contact with the back, and with the bottom, where it is hottest, is warmed and contributes at least one-half the whole effect. The great heat of the bottom makes its effect on the air of the room at least equal to that of the two ends. Sometimes a stove makes a part of the wall between two small rooms, and is found sufficient for both. In the better kind of houses, the stoves are placed next the passages and landing-places, so that they may be filled with fuel, and heated morning and evening, without the servants coming into the room; by which means much dirt and other inconveniences are voided.

If this manner of constructing stoves be compared with the ommon German stoves used in English workshops, the great uperiority of this stove, used by the northern nations, will be erceived, not only in respect to the quantity of heat it produces, but also with respect to the expense of fuel.

A fire lighted in a stove of this kind in the morning and the vening, with a small quantity of fuel, retains a strong heat during the whole of the day and night. Besides, these stoves are free from many other inconveniences which attend the common ones.

It may perhaps be objected, that the heat produced from these stoves must be unwholesome, as they deprive the air of its moisture, and that the air by being made too dry loses its elasticity; in consequence of which, respiration becomes difficult and laborious. These objections would appear of great weight, if we had not the example of the Russians, the Swedes, the Danes, the Germans, and in short, of all the inhabitants of the north of Europe, to show that those who are habituated to such stoves do not find them unwholesome.

The inconveniences here mentioned are indeed entirely removed by the following very simple method, which has been tried for ages, and invariably found to answer:—A vessel of glass, earthenware, &c. which has a large surface, and is very shallow, is placed on the stove and filled with water. This water insensibly evaporates, and restores to the air that moisture which the heat of the stove has deprived it of.

If orange-trees are exposed to the heat of such a stove, and the fire is not properly regulated, the plants grow yellow and lose their leaves, especially if the air is not changed, which in winter is not very conveniently done; but if a vessel of water be placed upon the stove, the evaporation of the water will preserve the trees.

It appears from the remains of the Roman villas that have been found in England, that houses, or at least the rooms attached to the baths which constituted their great luxury, were heated upon a similar principle. Except that the stove, or hypocaustum, was not placed in the room but under ground, so that it only communicated its heat by its upper surface, which formed the floor of the room, and was of equal extent with it.

The hypocaustum was in fact a low-roofed cellar with pillars in the centre, and a hollow flue round it to support the pavement of the room above it. A door near the floor served for the introduction of the fuel, and occasionally, no doubt, for the entrance of the stove-tender to clear out the soot. As three of its sides, and sometimes the greatest part of the fourth, were contiguous to the soil, there would be little expenditure of heat through them, and consequently nearly the whole force of the fire would be directed upwards into the apartment over it.

In the northern parts of Asia the Chinese and Tartars have adopted this mode of warming their apartments by the radiant heat of close stoves, as they are usually called.

The close stoves in the Chinese houses are most commonly, like the Roman, placed under the floor.

Fig. 53, represents the construction of these floor flues; *a*, is a large ash-pit sunk in the ground, for its whole depth; *b*, an opening in the front part of the roof of the ash-pit to allow the entrance of air to the fire-room, and occasionally serving as a man-hole, to allow a person to descend into the pit and clear

it of the ashes; *c*, the feeding-hole of the fire-room usually left open; *d*, the stoking-hole, which is also left, in general, open. At the back of the fire-room is a long narrow vent placed, not horizontally as in our melting or founder's furnaces, but vertically, and its length is nearly equal to the whole depth of the fire-room.

The smoke and heated air pass through this vent into a deep narrow main flue, *f*, which runs across the seat of the room, from the wall where it enters to nearly the opposite side, and has generally two side branches from about the middle of its length reaching to the other two sides. This deep flue is covered with bricks, but there are left on the sides openings through which the smoke may escape. These openings are made in the cross branches, rather than in the main flue itself.

The pavement of the room is double, the lower pavement is, however, in some cases, made only of clay and sand well beaten down. The upper pavement is of large square tiles, supported at the distance of a few inches above the lower pavement, by cubic bricks. Two horizontal flues, *l*, are constructed between the double pavement, one on each of two opposite sides of the room. These flues allow the entrance of the smoke and hot air which has circulated between the double pavement into one end, *m*, and discharge it into the chimney, *n*.

Great pains is taken in cementing the pavement to prevent the smoke from entering the room. In the royal apartments the tiles are of porcelain, two feet square, and laid double, with the joints of the one not coinciding with those of the other.

There are several various ways of building these floor smoke-flues, called kon kang, and ti kang by the Chinese.

In the best houses the furnace is built either in the court yard, and generally against the wall that faces the north, or in a servants' hall adjoining the room to be heated. And the chimneys are built on the outside.

In the houses of the poor the furnace is built in the room, and has a boiler set upon it to supply the family with water. The chimneys are also built up in the room, for being very thin they add to the effect.

The Chinese have also a kind of these stoves, which they call a tong kang, or wall stove. The north, or back wall of the house being made double, but tied together by long bricks, and thus assimilating to the cellular walled hot-houses of our gardens.

In the best houses they burn nothing but wood, or a kind of coal which does not smoke, but burns like tinder: the middling class burn pit-coal broke into the size of coarse gravel, mixed with one third, or even one half, of a yellow clay, and made up into bricks; the poor in the country use furze, straw, cow dung, or whatever they can get.

The Chinese are led by their philosophy to endeavour to sweeten the air from the noisome vapour of the fire, and to absorb the fiery particles dispersed throughout the air of the room, by keeping bowls of water in them. The gold fishes which are kept in these bowls are both an ornament and an amusement.

There can be no doubt but that the floor smoke-flues might be advantageously adopted in England in labourers' cottages, and the ground floors of houses, especially of those which are seated in a moist soil.

Father Gramont, the missionary, to whom we are indebted for this information, has omitted to state whether the fire is allowed to burn until the fuel is consumed, or whether, as in the close stoves, so soon as it is in complete combustion, the outlet

of the furnace is stopped, and the heat already produced left to radiate slowly through the walls. He only says, that very little fuel is required, and that although the open air at Pekin, is in winter, at —9 to —13 degrees Reaumur, and the fronts of the houses, which generally face the south, are scarcely any thing but oiled paper windows, two of the upper panes of which, at different ends of the room, are always left open for ventilation, yet the rooms are at 7 or 8, of Reaumur's own scale.

Smoke Flues for Plant Houses.

The most general mode of heating houses for keeping plants is by fire and smoke flues, similar to the Swedish and Chinese stoves, and, on a small scale, this will probably long remain so: for with good air-tight flues, formed of well-burnt bricks, and tiles accurately cemented with lime putty, and arranged so as the smoke and hot air may circulate freely, every thing in culture, as far as respects heat, may be perfectly accomplished.

Where a house of considerable length and contents is to be heated, it is generally deemed better to increase the number of furnaces than to increase their size; for, when the latter practice is resorted to, they are necessarily projected so far into the shed, or otherwise kept back from the house, that a great part of the heat is lost in the mass of brick-work which surrounds them. Small furnaces, on the contrary, may be built in great part under the walls or floor of the house.

In countries where turf, wood, or inferior coal is used for fuel, the chamber of the furnace must be large; on the contrary, when the best coal, cinders, charcoal, or coke, which three last are the best fuel for hot-houses, as having no smoke, is used, they may be made smaller in proportion to the different degrees of intensity of the heat produced by these different materials.

In fixing on the situation of furnaces, care must be taken that they are always from one to two feet under the level of the flue, in order to favour the circulation of the hot air and smoke, by allowing it to ascend.

As to the size of hot-house fire-places, the door of the furnace may be from ten inches to one foot square; the fuel chamber, from two to four feet long, from eighteen inches to two feet wide, and of the same dimensions as to height. Every thing depends on the kind of fuel to be used. For Newcastle coal, a chamber two feet long, eighteen inches broad, and eighteen inches high, will answer as well as one of double the size, where smoky Welch or Lancashire coal is to be used.

In the modes of constructing flues for heating houses for keeping plants there is considerable variety.

The sides of common flues are commonly built of bricks placed on edge, and the top covered by tiles, either of the full

width of the flue, outside measure, or one inch narrower, and the angles filled up with mortar. Where a stone that will endure fire heat without cracking, is found to be not more expensive than tiles, it is generally reckoned by far preferable, as offering fewer joints for the escape of the smoke. Such stones are sometimes hollowed on the surface, in order to hold water for the benefit of plants in pots, or for steaming the house.

Of other improvements which have been proposed, that of making them broad and deep, agreeably to the Dutch practice, has been recommended by Stevenson; that of making them narrow and deep, agreeably to the practice in Russia, is recommended by Oldacre; and that of using thin bricks with thick edges, by S. Gowen, takes up less room than any other brick flue, the covers and the common bricks being quite thin, the base requisite for building them on one another being obtained by the thickness of their edges, which is equal to that of common bricks.

Can-flues, long since used by the Dutch, imbedded in sand, and for the last fifty years, occasionally, in England, consist of earthen pipes straight or rounded at the ends for returns, and joined together by cement, placed on bricks. They are rapidly heated, and as soon cooled. None of the heat, however, which passes through them, can be said to be absorbed and lost in the mass of enclosing matter. They are, however, only adapted for moderate fires; but, judiciously chosen, may frequently be more suitable and profitable than common flues; as, for example, where there are only slight fires wanted occasionally, or where there is a regular system of watching the fires, in which case the temperature can be regulated with sufficient certainty.

Cast iron flues have also been recommended on account of their durability, but unless they were to be imbedded in sand, or masonry, they are liable, in an extreme degree, to the same objections as can-flues.

The size of flues is seldom less than nine inches by fourteen or eighteen inches, inside measure, which suits a furnace for good coal, whose floor or chamber is two feet long, eighteen inches wide, and eighteen inches high.

The furnaces from whence the flues proceed are generally placed behind the back wall, as being unsightly objects; but, in point of utility, the best situation is at the end of the front wall, so as it may enter the house, and proceed a considerable length without making an angle. Utility, however, is generally sacrificed to beauty in this department of gardening.

The direction of flues, in general, is round the house, commencing always within a short distance of the parapet, and after making the course of three sides, that is, of the end at which the fire enters, of the front, and of the opposite end, it returns,

in narrow houses, near to or in the back wall, or, in wide houses, up the middle, forming a path; and in others, immediately over or along side of the first course. In all narrow houses this last is the best mode.

The power of flues depends so much on their construction, the kind of fuel, the roof, mode of glazing, &c. that very little can be affirmed with any degree of certainty on this subject. three thousand cubic feet of air are, in general, enough for one fire to command in stoves or forcing-houses; and five thousand in lean-to green-houses. In houses with glass on all sides, two thousand cubic feet are enough in stoves, and three thousand cubic feet for green-houses. The safest side on which to err, is rather to attach too little than too much extent to each fire; as excessive fires generally force through the flues some smoke or noisome vapours; and, besides, produce too much heat at that part of the house where the flue enters.

Sometimes the flues are carried under ground to some distance from the hot-house, and the chimney carried up in a group of trees, or otherwise concealed. This practice is most suitable to detached buildings, formed of glass on all sides.

When fuel that yields no soot is used, then, instead of straight lined flues, a cellular wall, as hereafter described in treating of steam heat, may be used.

As soon as smoke flues attain such a length that the temperature of the heated air is less than 212 degrees Fahrenheit, cast-iron pipes might be used with advantage, because they would afford more heat, and at the part of the flue most distant from the fire, where heat is most required.

By the usual method of employing a slow conductor for the whole length of the flue, a part of the heat is lost, and the smoke escapes at an elevated temperature. A high chimney will also be found to make a considerable difference in the effect that can be gained from smoke-flues; because a rather forcible draught is required to make the smoke circulate through much extent of horizontal flues.

The most serious evil in smoke-flues is the great number of chimneys requisite; though this might be obviated by a chimney of considerable height being built where it could most conveniently be seated, and into which the flues of the separate furnaces might be conducted either under or above ground.

Steam Heat.

Steam is a vehicle for conveying heat, which, when employed at a low pressure, will never give to the vessel containing it a greater heat than that of boiling water, or 212 degrees; and when the surface is of a proper material, the heat produces no

sensible effect on the air, can be conducted to any part of a building with the utmost facility, and is perfectly safe.

One important advantage is attained by a steam apparatus, which distinguishes it from every other method of distributing heat, which is, that it can be extended to a very great distance from the boiler in every direction. We can cause it to ascend, descend, or move horizontally with equal facility; the loss of heat is inconsiderable in conveying it to a distant point; hence, one single fire is sufficient for an immense establishment, and this one may be placed where the smoke of a chimney is least offensive, and its appearance least objectionable. The distance from the boiler to the end of the most distant house, at Messrs. Loddige's of Hackney, is about eight hundred feet, and it does not appear to be carried to the greatest extent.

But, wherever steam is employed, it should be under the direction of a person competent and willing to attend to it, and having no other business to take off his attention. For, though in such hands it is perfectly safe, and easily managed, it is by far too complicated to be trusted in the hands of common servants, who are occasionally employed in other places. The apparatus must be kept in order, and though only a small degree of attention be necessary for that purpose, it does not admit of neglect. The supply of fuel, also, requires more frequent renewal than in common furnaces.

"It is," as Mr. Tredgold observes, "very commonly asserted, that steam heat is more economical than that of smoke-flues; how the comparison has been made is not known; but he must be a novice in the science of heat, that cannot produce nearly the same effect by the one as by the other, all other circumstances being the same. In either method it is easy to mismanage things in such a manner, that no more than half the heat will be effective in warming the intended space; and by selecting cases for comparison, you may make either appear to be the best method, as far as regards economy of heat. Where a proper attention can be given, steam is preferable; but in other cases, flues will be found to answer better."

In ordinary dwelling-houses, it does not appear to be desirable to employ steam-heat alone; but it may always, in large houses, be made an auxiliary mode of procuring warmth and assisting ventilation.

A large room is seldom comfortably warmed by open fires; and halls, staircases, and passages, cannot be warmed by them without a great waste of fuel. But the most advantageous method seems to be, to unite the two principles of warming; that is, in the rooms to use the radiant heat of an open fire, and also supply the rooms with air partially warmed; while the passages, halls, staircases, and workshops, are warmed by proper steam-vessels.

The quantity of heat required will indeed be greater, as the quantity of glass is greater; but, from motives of economy, the invigorating influence of an abundant supply of light ought never

to be excluded, particularly in schools and work-rooms; for the more we exclude light and air, the more pale and languid we shall render the persons who inhabit them. By making the windows double, the loss of heat may be reduced to less than one-third, without sensibly lessening the quantity of light.

The quantity of steam has been hitherto proportioned to the cubic foot of space to be heated: a superficial foot of steam-pipe, it is said by Mr. Buchanan, will heat about two hundred cubic feet of space, or a cubic foot of boiler two thousand cubic feet of space.

These proportions are given for cotton mills, but they are perfectly useless in any instance where a different degree of ventilation is necessary, as in hospitals, or where a greater proportion of window is necessary, as in houses for growing plants.

There are two causes of loss of heat in buildings—the cooling effect of the external air against the windows, or other external surfaces of the building; and the quantity conveyed away by the impure air, which must be removed by ventilation, the outlets by crevices, and other openings. These will always be measured by the quantity of air that is to be heated to the temperature of the room, from that of the external air; and, therefore, the fuel or the surface of steam-vessel that will be sufficient to heat that quantity of air, will sustain the room at the proposed temperature.

Hence the quantity of surface of steam-pipe that will maintain a room at a given temperature, is easily calculated, if the degree of ventilation, and the loss of heat, be previously estimated.

To make this calculation in the proper manner, the temperature of the external air, or of the air that supplies the ventilation, is to be known at the extreme case of cold, which, for the day, may be taken at 30 degrees; but for night may generally be assumed at once, to be at zero of Fahrenheit's thermometer, as the cold is seldom more intense in this climate. The temperature at which it is proposed to maintain the room, or place to be heated, at the same season of cold, is also to be settled, and the quantity of air by the minute, which must be raised from the temperature of the external air to that of the room, in order to supply the loss of heat by the glass of the windows, the crevices around the windows and doors, and the ventilation required for the number of people in the room.

Each person in the room may be estimated to require a supply of four cubic feet of air, but in sick rooms six feet by the minute, each superficial foot of glass to cool a cubic foot and a half, and the crevices around each moderate-sized door or window, opening to the external atmosphere, to cool eleven cubic feet in the same space of time.

In houses for plants the crevices of the panes may be estimated to cool as many cubic feet of air by the minute as are equal to the length of the house in feet multiplied by half the greatest height, independent of the cooling action of the doors and sliders.

These points being ascertained, Mr. Tredgold gives this rule to find the necessary surface of steam-pipe: multiply each cubic foot of air to be heated by the minute, by the difference between the temperature the room is to be kept at and that of the average external air, in degrees of Fahrenheit's thermometer, and divide the product by the difference, previously multiplied by 2.1, between 200 and the temperature of the room. The quotient is the quantity of surface of cast-iron steam pipes that is required.

Mr. Tredgold, in his Principles, has shown that a bushel of Newcastle coals by the hour, will supply heat to 1820 feet of surface of pipe in a room at 60°

2100 ditto	at 80°
2500 ditto	at 100°

If the condensed water cannot be returned to the boiler, about one-twelfth of the heat will be lost; and consequently, these quantities of surface must be reduced by one twelfth.

In addition, there will be required as much fuel as will supply the waste of heat at the boiler, and if no means are employed to prevent loss of heat at its surface, the loss of heat at the boiler will often be equal to the effect of the steam-pipes it supplies, and in small boilers the proportion of this loss will be greatest.

On a gross calculation, it will require a bushel of coals, every winter, for each six cubic feet of air which is to be heated by the minute.

Another consideration is, to know the quantity of water that will be condensed in a given time, because then, where the condensed water is not, or cannot, be returned to the boiler, the supply of water that will be required can be estimated. In a room at 60°, 182 square feet of cast-iron steam-pipe will condense a cubic foot of water in an hour; at 80° it will require 210 feet; and at 100°, 252 feet to condense the same quantity.

Feeding Apparatus for Steam-Boilers.

The apparatus required to supply steam for heating rooms and plant-houses, is perfectly analogous to that used in the general chemical laboratory already described; but it is usually made on a larger scale; and should any part of the top of the boiler be exposed to the open air, it is made double, and the interstices carefully filled with stifled charcoal ground to powder.

As these large boilers require a considerable supply of water, it is usually, and almost absolutely necessary, to furnish the steam-boilers used for this purpose with an apparatus by which they may supply themselves with water from a cistern, which must be raised so much above the level of the water as may counterbalance the expansive force of the steam, according to the rules laid down in page 78, namely, two feet .1 in height, for each pound of pressure the steam is worked at above the pressure of the atmosphere.

The most usual kind of feed-pipe is shown at *a*, *b*, fig. 54. The lower part of this pipe is turned at the end to prevent steam rising through it. Where it passes through the top of the boiler, it is made steam tight, and fixed in a vertical position. The top of the pipe terminates in a small cistern head, *c*, which is kept supplied with water from a large cistern, *d*; and at the bottom of the small cistern, *c*, there is a conical valve opening upwards, connected by a chain to a lever, *e*, which turns on a centre with a wire, *f*, attached to the opposite end. This wire passes through an air-tight stuffing box to a flat stone in the boiler, which is so balanced by a weight, *g*, on the opposite end of the lever, as to float on the surface of the water.

Its action is performed in this manner:—When part of the water is evaporated from the boiler, the stone-float descends with the water's surface, and consequently raises the conical valve; now the small cistern-head, *c*, being kept constantly full of water, by a pipe from the cistern, *d*, as soon as the valve is raised, water enters the boiler, and when it is filled to the proper level, it raises the stone-float, and shuts the valve, till a repetition of the operation becomes necessary.

The principal circumstance to be attended to in the construction of this apparatus is to make the height of the water in the small cistern sufficient to balance the strength of the steam. For if this height be too small, the water in the boiler will be forced up the feed-pipe by the pressure of the steam, and be driven out at the valve. Therefore, when this height is correctly arranged for the greatest strength of steam it is proposed to employ, which is generally two pounds and a half to the square inch, this pipe answered the purpose of a safety valve; and in boilers for steam apparatus, where the stop-cock of the steam-pipe is made so that it cannot be perfectly closed, no other safety valve is necessary. For the steam will always flow through the feed-pipe as soon as the pressure exceeds the head of water in the cistern; with this view the part of the pipe, *a*, *b*, may be made larger, and also the valve. And a small open pipe, *h*, will allow air to enter if a vacuum be formed, or water to escape whenever the pressure is too great.

There is a more simple kind of feeding apparatus, in which the depression of the stone-float opens a cock in the pipe from the cistern; the height of the cistern being regulated as for the preceding method.

Fig. 55 represents this method: *a*, is the pipe for supplying the boiler with water; *b*, a wire by which the stone-float on the surface of the water moves a cock, *c*, in the pipe, *a*, to admit a fresh supply of water when necessary. *D*,* is a small pipe for admitting air to the boiler in the case of a vacuum being formed, or to allow steam to escape if it become too strong.

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* This pipe is entirely unnecessary, where the stop-cock is used instead of the puppet-valve, fig. 54, as the formation of a vacuum in the pipe below the stop-cock, can in no way operate to prevent the opening of the cock.—Am. Ed.

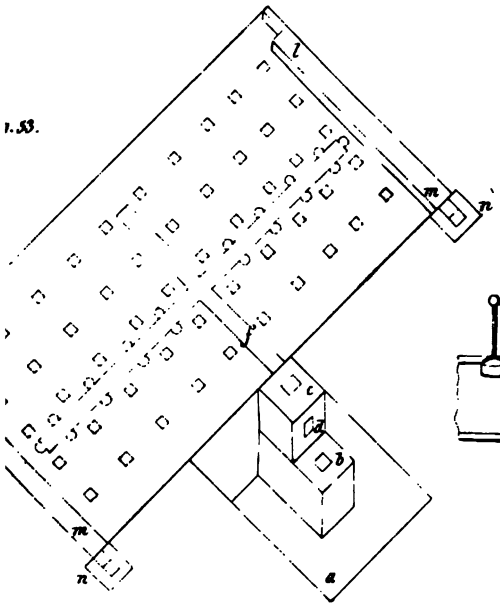
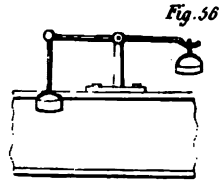


Fig. 56.



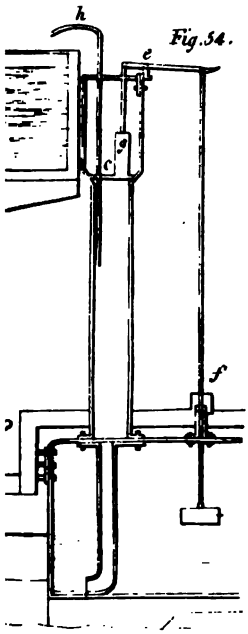
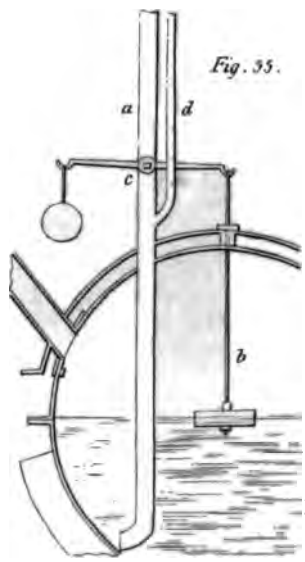


Fig. 54.

Fig. 55.



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Steam-Pipes.

In respect to the materials for pipes and vessels, it is most ual to employ cast-iron for steam-pipes and vessels; and it is stly esteemed preferable to all other metals for this purpose, ecause it does not, by being heated, exhale any thing injuri-s. It may be formed of any shape that is most convenient, d is strong and durable.

Tinned iron is less expensive than cast-iron; but it is also less rable; besides, vessels and pipes formed of this material must provided with valves to prevent them collapsing.*

Fig. 56, shows the form of the valves which open inwards, and in which the lve is balanced by a weight at the opposite end of the lever.

Copper is objectionable, because it exhales a peculiar odour hen heated, which is neither agreeable nor healthy. But in ying-rooms it will be required, because iron would injure the en, &c.

In copper pipes it will also be necessary to place valves to event them collapsing.

Lead is wholly unfit for pipes to convey steam, because pipes lead become longer every time they are heated, and ulti-ately crack.

For small pipes, it will be necessary to use wrought-iron ones, ch as are made for gas-pipes.

In respect to the space for steam, when the supply is to be ntinual, if it be too large, the distributing apparatus will be g in filling; if it be too small, the steam will flow with diffi-lty.

The diameter of pipes should never exceed six inches, nor ght they to be less than three inches where the quantity is nsiderable. When the pipes would exceed six inches, to gain e necessary quantity of surface, then it would be better to ve two pipes; and with a very little extra trouble it can be ar-nged so that both the pipes, or only one of them, may be ated. But where the condensed water is to collect in the pes, and to supply heat when the steam has ceased to flow, rge pipes will be best. Those of cast-iron will be of sufficient rength when cast as thin as they can be formed, so as to be rfect. This can be done with somewhat less than three-ghths of an inch of thickness.

In elegant rooms, pipes cannot be employed with propriety less concealed; and therefore other forms of vessels must be

* A still greater objection to the use of tinned iron is, that it would require om 6 to 8 times the extent of surface to produce a given effect, when com-ared with cast iron; that is, on the supposition, that the tinned iron has the olish of the article when new, and the iron its usual dark and dull surface.—M. Ed.

used. The cavity between two hollow cylinders or prisms, the one inserted within the other, being filled with steam, it will offer a considerable extent of surface without occupying much space, and may be made to appear as a pedestal for a bust. Even ornamental columns, pillars, vases, and the like, may be adapted to contain steam.

It is, however, necessary to provide against the expansion which all bodies suffer when they are heated. This expansion differs in every metal;—one-eighth of an inch for every ten feet in length of cast-iron pipe must be allowed for its expansion; one-eighth of an inch should be allowed for expansion of tough iron pipes, for every eight feet in length; two-tenths of an inch should be allowed for the expansion of copper in every ten feet in length.

The allowance for the expansion of lead approaches nearly to seven-twentieths of an inch for each ten feet in length. But in lead pipes, employed to return the condensed water to the boiler, one-fifth of an inch for every ten feet will be sufficient.

That pipes may be at liberty to move freely as they expand, they should be supported on rollers.

In heating new buildings by steam, vertical pipes have been employed; and, with an idea of economy, these pipes have been made to answer as principal supports for the buildings; but the expansion of the pipes is a great objection to this mode, and it is a considerable advantage, in all cases, to have the heating apparatus distinct from the fixed parts of a building, so that it may be renewed, altered, or repaired, without injury to the substantial parts of the structure: this, with the consideration abovementioned, more than compensate for any extra room required to have the apparatus distinct.

The usual and the best mode of joining pipes, &c. is by flanches. In the joint should be inserted a flat plait of slightly twisted hemp yarn, which has been previously saturated with stiff white lead paint. If a little red lead be mixed with the white lead paint, it will dry sooner and become considerably harder. And flannel, or mill-board, may be used in the place of hemp.

Some use iron cement for the joints; but where white lead and hemp or mill-board can be used with propriety, it is preferable.

Wrought-iron pipes may be joined by making each of the lengths that are to be put together to screw into a piece of pipe of larger diameter. They may also be screwed into cast-iron pipes, cylinders, &c. so as to serve as branch-pipes, connecting-pipes, and the like.

Where, in consequence of turns and angles, no other mode of avoiding the effect of expansion will apply, the pipes may be connected, by a short length of smaller pipe, to slide in a stuffing-box in one of the pipes.

In every part of the distributing apparatus it is necessary to prevent any considerable quantity of water collecting, as it condenses the steam so rapidly as to endanger the boiler and pipes being forced together by the pressure of the atmosphere, should they not be firm enough to resist the pressure.

When it is possible to have the boiler at a lower level than the pipes and other steam vessels, it is best to return the water of the condensed steam into the boiler again, because it not only saves fuel, but also requires a smaller supply of fresh water; an object worthy of attention where water is scarce.

In conducting steam heat to the place where it is to be applied to some useful purpose, it must be prevented from being lost in the passage.

If a steam pipe be simply placed within another pipe of larger diameter, and kept in the middle by slow conductors of heat, it will lose only a small portion of heat.

For conveying steam-pipes to a considerable distance under ground, in a dry soil, a drain may be formed, and fitted at the bottom with brick-bats, small-stones, or the like open materials; and the pipe laid in so as to be surrounded, on every side, with about three inches in thickness of dry ashes, covered with a coat of well-mixed clay over the top, to keep off the water, and also with such a depth of earth as may be necessary to prevent it being disturbed.

Condensed Water-Pipes.

The water ought to be returned to the boiler in all cases where we do not retain the whole of it in the pipes, to afford a supply of heat after the fire is burnt out. The most simple and obvious plan of doing this is to give the pipes a descent to the boiler, where it can be placed at sufficient depth for that purpose.

The best plan is for the steam-pipes to proceed in the nearest course to the highest point where steam is required, and then descend to the lowest, from which a small condensed water-pipe may return the water to the boiler.

This condensed water-pipe ought to be surrounded with slow conductors of heat, so that as little as possible may escape. When the boiler cannot be placed at a sufficient depth below the lowest place where heat is required; the water can, in some cases, by the power of steam to support a certain column of water, be returned to a higher level in this manner.

In fig. 57, *a*, shows the cistern to which it is to be returned; and, *b*, the lowest part of the steam-pipe; *c*, *d*, is a pipe from the steam-pipe to the cistern, with a valve at *c*, to prevent the water forced into this pipe, by the pressure of steam in the steam-pipe, from returning. The arch, *d*, must be above the level of the water in the cistern, and the height, from the end of the steam-pipe to this arch, not more than two feet and a quarter for each pound of pressure upon a square inch.

Where sufficient room can be obtained, the most certain apparatus for taking off the water of condensation, is the inverted syphon, which has been long used for that purpose.

Fig. 58, represents a syphon of this kind; in which *a*, is the lowest point of the steam-pipe, and of course any water that collects in the pipe will flow into the syphon, *b*, *c*, *d*, and run out at *c*, either to waste or into a hot-water cistern. The depth, *a*, *b*, should not be less than is equivalent to the force of the steam in the pipes; consequently, if the steam should be worked at four pounds to the square inch, the column of water, *b*, *c*, should not be less than ten feet, and even, with this pressure, there will be considerable oscillations, unless a valve be placed at some point in the branch, *d*. When the legs are both filled with water and at rest, this valve should open, and be constructed so as to close whenever the water has a tendency to flow back into the pipe.

The syphon should be large enough to take away all the condensed water with ease; but it should not be too large, because there will be a loss of heat in the leg, *d*, from its being filled with steam; and in all cases, the syphon should be carefully protected from freezing.

When sufficient depth cannot be got for a syphon, a steam-trap or valve, to open by a float-ball, is employed.

Fig. 59, represents this apparatus; *a*, is the lowest point of the steam-pipes, to which a cast iron box, *b*, *c*, is attached; as also a blow-pipe, *d*, to let out the air which the steam drives before it, when it is first let on. The box, *b*, *c*, has a pipe, *e*, at the bottom to let out the condensed water flowing into the box from the steam-pipes, and either let it run to waste, or collect it for other purposes. In the box, *b*, *c*, is a conical valve, *f*, which stops the entrance of the condensed-water pipe, *e*; to this valve is affixed a hollow copper ball, *g*, of sufficient size to float it, and which is kept in a proper position by the wire, *h*, running through a stay in the upper part of the box. When, therefore, steam is condensed, the square box will fill with water, which will float the hollow cylinder, consequently the water will escape, and run by the pipe, *e*, into the drain at all times, when the quantity in the box is greater than is required to float the cylinder; when there is less than will float it, the valve of course closes.

Cellular Hot Walls.

To save the expense of cast iron pipes, the gardeners have invented the cellular wall, which is built with cells communicating with each other from the surface of the ground to the coping. The main steam-pipe is introduced in the lower part, and conducted along the foundation, and the vapour allowed to ascend through the cells to the top. It condenses in the masonry, and heats uniformly the whole material of the wall. If the height does not exceed ten or twelve feet, these walls may be formed of bricks set on edge, each course or layer consisting of alternate series, of two bricks set edgeways and one set across, forming a thickness of nine inches, and a series of cells nine inches in the length of wall, by three inches broad. The second course being laid in the same way, but the bricks alternating or breaking joint with the first, the cells will of course communicate with the others.

The advantages of this wall are obviously considerable in the

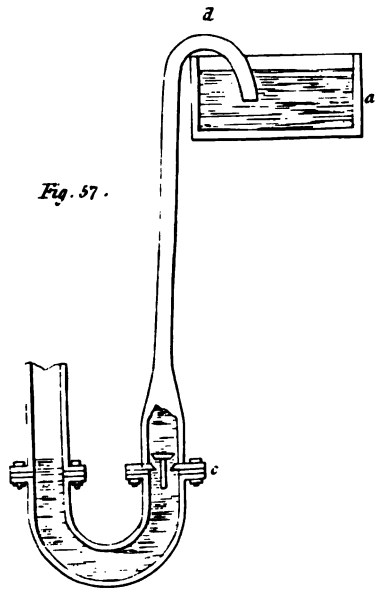


Fig. 57.

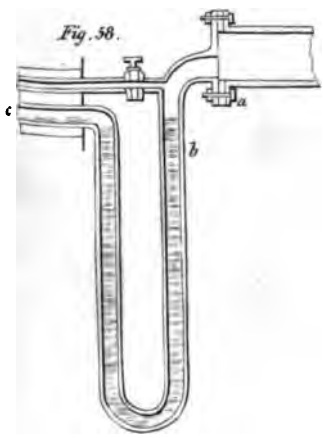


Fig. 58.

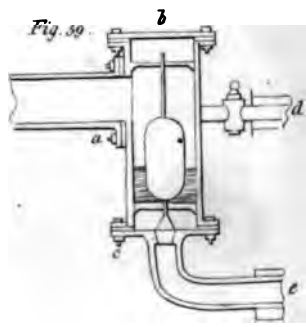
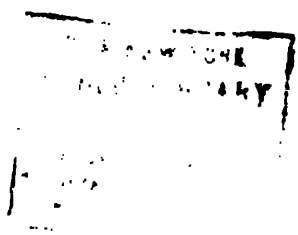


Fig. 59.



saving of material, and in the simple and efficacious mode of heating; but the bricks must be of the best quality, and the mortar such as will not be injured by alternate drought and moisture. For this purpose Stourbridge or London bricks will be found the best, and either common mortar, mixed with powdered ferruginous stones, pozzolana or decomposed lava, tarras or decomposed basalt, or pure lime and clean coarse sand used in a recent state.

This wall has been tried in several places and found to succeed perfectly as a hot wall, and at ten feet high to be sufficiently strong as a common garden wall, with a saving of one brick in three. The same idea may be advantageously applied to flues for heating hot-houses by steam, and for other purposes.

There are two purposes for which steam heat is thought to be particularly useful: first, the maintaining of rooms in a more equal temperature than that afforded by our common open fires, without having recourse to close stoves for that purpose, as there exists an absurd prejudice against these stoves in the public mind; and, therefore, this operose method is chosen in preference to the more simple method which they offer of effecting that purpose.

Secondly, the drying of linen, cotton, or woollen cloth, in the several operations of bleaching and dyeing.

Madeira Rooms, or Rooms of equal Temperature.

The numerous and distressing cases of consumption in our climate, have directed the attention of medical men to the means of procuring for their patients the advantages which are said to be derived from a removal to warmer situations, by keeping up an equal temperature in their chambers.

To bring together and mix a great many persons, labouring under the same disease, must too often be exceedingly hurtful; and to provide distinct apartments for each, would be attended with too much expense to be practicable; and when people are languishing under disease, what place is like home, sweet home!

The room should first be made as air-tight as possible, by pasting strips of canvas and paper over all the openings; and a double door may be added: the additional door being made as small as will answer the purpose. The chimney must also be closed up, and the window have double sashes.

The next object should be to admit as much warmed air as will ventilate the room, and allow the other to escape at the ceiling. The warm air admitted should be five or six degrees below the temperature the room is kept at, as the rest of the warming ought to be effected within the room. The quantity of air to be warmed for ventilation, for an ordinary-sized room,

will be about twelve cubic feet by the minute, and if the room is to be kept at sixty-two degrees, the air should be heated to fifty-six degrees before it enters. This may easily be effected by means of a boiler placed within the hob of a kitchen fire, or a small portable boiler of the kind used for steam-baths, with tin-plate pipes.

A three-gallon boiler, with an equal space for steam, will be sufficient. The pipes should be so placed that the condensed water may return to the boiler.

The air to be warmed should be brought from the external air to pass through the wall into an iron or tin box, containing the steam-pipes: the air being warmed, it is made to rise through a pipe at the top of the air-box into the room. In order to prevent the loss of as little heat as possible, the air-box ought to be enclosed in a wooden case.

A pipe of the same diameter will be required for the escape of air at the ceiling. The size of both these pipes should be about three inches and a half diameter; and they should each be provided with a register to regulate them.

The quantity of steam-pipe to heat the air-box to fifty-six degrees, when the external air is at thirty degrees, would be one superficial foot, if they were of cast iron; but it will require nearly two superficial feet of tin-plate to give the same quantity of heat, hence the surface of the pipes should be two feet, or they may be four inches diameter, and one foot long. The steam should be brought by a small pipe from the boiler into the upper pipe of the air-box, and from thence into the lower one, and return, when condensed to water, by a small pipe to the boiler.

About four feet of surface of cast iron pipe or vessel, or eight feet of surface of tin-plate, will supply sufficient heat to keep a moderate-sized room at sixty-two degrees.

An indexed cock should be placed in the pipe, so that the supply of steam may be regulated by any person in the room.

[If we admit the correctness of the remark of Mr. Tredgold, just quoted, in relation to steam heat and smoke flues, "that he must be a novice in the science of heat, who cannot produce nearly the same effect by the one as by the other, all other circumstances being the same," of which there is some reason to doubt; there is but a single argument in favour of the employment of the former, and that is its absolute safety. This is certainly a very weighty consideration, and particularly in cotton factories, and other buildings peculiarly exposed, from the nature of their contents, to fire. But the Belper, or Wakefield stove, shortly to be described, approaches so near to this desirable point that the risk in its employment is extremely small. One of the principal objections to the use of steam for these pur-

poses is the great expense of the apparatus compared with that of the hot air flues. I am not prepared to state with precision what the difference in the expense of the apparatus is for warming in these two ways, but do not hesitate to say that at the present price of iron castings and boilers in New England, the arrangements for steam would exceed those for the hot air stoves by at least, four or five times. Nor is this great difference in expense compensated by greater permanency in the former apparatus when once obtained; on the contrary the wear and tear must, I think, be much greater;—cast iron pipes will, indeed, last a long time, but no species of apparatus is worked at greater expense for repairs than large steam boilers.

The want of ventilation is a still more serious objection to this mode of heating; those, who have experienced the confined and suffocating air of a cotton mill heated by steam and the fresh summer-like atmosphere of one warmed on the hot air principle, cannot hesitate for a moment to decide in favour of the latter on the score of healthiness, comfort and cleanliness. It may, it is true, be said, that, although the arrangements for steam do not furnish the necessary ventilation, they do not preclude the adoption of other means of effecting that object. But the truth is, there is no means of ventilating an apartment so simple, and so effectual, as by connecting the two operations inseparably together. The importance of a pure atmosphere is seldom sufficiently appreciated by the generality of people to ensure that attention to the subject, which it really demands; and accordingly we find that in large establishments, as well as in private dwellings, where the necessary means are provided by apertures to be opened and shut at the pleasure of the occupant, and in accordance with his view of the propriety of the operations, the business is almost sure to be neglected. The great mass of mankind are the creatures of sense rather than of reflection; remote and contingent evils lose their relative importance when compared with those, which appeal directly to the senses. The slow and gradual, but certain and pernicious, influence of an insalubrious atmosphere is little heeded in comparison with the more immediate effects of heat and cold. It should therefore be the aim of the architect to combine the two operations of warming and ventilating, which cannot, or at least has not, been effected where steam is employed. The writer is led to these reflections from having often contrasted the pallid and sickly countenances of the tenants of the Manchester factories and work-shops with the comparatively fresh and healthy complexions of similar classes in New England; and this difference is the more remarkable since the general complexion of the inhabitants of England, even of the

humblest of the labouring classes, is more florid and healthful in appearance, than the people of our northern and eastern states: these results are doubtless in part owing to the operation of other causes, such as differences in food, clothing, &c., but no one circumstance appears to him to have contributed more to depress the physical character of the British manufacturing operatives than the almost universal practice of warming their large mills and work-shops by steam.

It might be supposed that the ventilation proposed in connexion with the hot air stoves, would only be effectual during the season of using fire, but it will be seen that this apparatus is equally effectual for this purpose where no fire is used.]

Steam Drying-Rooms.

Steam-heat has been found less injurious to cloths of all kinds than any other method; for it neither communicates a harsh feel, nor impairs the lustre nor colour of the brightest dyes.

[This notion was for a long time entertained by calico printers and bleachers, but is, I believe, now generally discarded, except by the common workmen. The writer can affirm from the most ample experience that artificial heat produced in any other way, provided the atmosphere is preserved equally free from smoke and dust, will answer all the valuable purposes of steam-heat. The harsh *feel* sometimes imparted to cloth in drying by stove heat is the effect only of too high a temperature. The adoption of steam, or stove heat must be determined by considerations of expense altogether.]

It may be applied to drying muslins, calicoes, linens, yarns, or paper, and to laundries in domestic economy.

The process consists in confining the heat to a closet of sufficient magnitude to receive the goods to be dried, and so contrived, that the workmen can change them with facility, without being exposed, in any material degree, to the intense heat and moisture of a drying-room.

Besides the inestimable advantage of being more healthy, this mode of drying is also more economical; because we can employ a temperature, and a current of air, which it is difficult to render at all effective in any other mode.

It will be obvious that dry air will act most powerfully; and, as the external air is frequently very damp, whenever that is the case, the manager of the drying-stove should admit air more sparingly, and work at a higher temperature, otherwise there will be a waste of fuel.

The atmometer of professor Leslie would be a useful instrument in a drying-room, as it measures the quantity of moisture exhaled by a humid surface in a given time. For though its

indications are not to be relied on for many meteorological inquiries, it is sufficient for the purpose here proposed.

The walls of the drying-closet should be of such a nature that they may absorb only a small quantity of moisture; and for this purpose they may be lined with glazed tiles.

Small drying-closets for private families, may be made entirely of wood; the effect of warping must be prevented by employing narrow strips, ploughed and tongued together, and fastened with copper nails, or wooden pins, as iron cannot be employed, on account of the rust that would be formed.

The frames on which the cloth is hung, should have wheels to each, in order that they may be easily drawn out. Frames suspended as the sashes of a window, may be often adopted. The space through which they are drawn out, or moved in, being provided with doors to shut close. There should be at least one spare frame, so that the drying-room may be kept constantly full.

The air should be heated by a portion of the steam-pipes, before it enters the real drying-room, or closet; and there should also be more pipes between the frames, for elevating the temperature of the goods. The outlets for the air at the top of the drying-closet must be provided with a regulator. There must also be another register to regulate the admission of cold air to the air-chamber.

The weight of water which is absorbed by cloths, is very different.

	Weight dry.	Weight wet.	Weight of water absorbed.
Flannel	1 pound	3 pounds	2 pounds
Calico	1 pound	$2\frac{1}{8}$	$1\frac{1}{8}$
Linen	1 pound	$1\frac{3}{4}$	$0\frac{3}{4}$

Mr. Tredgold says that the most economical rate of drying will be, when the quantity of moisture evaporated is eight parts in one hundred, of the whole quantity the goods contain, in one-thirtieth of the time it is intended each piece shall remain in the drying-room. The heat which may be taken as the most desirable to work at in practice, is ninety degrees. In goods of a thick texture, a longer time and a lower temperature must be employed.

In respect to drying cloth of any kind, Mr. Tredgold, from his experiments, estimates that it will require thirty cubic feet of warm air, to carry off the moisture of each square yard of cotton cloth, that the quantity of steam-pipe required for a piece of twenty-five yards is 138 superficial feet of copper pipe, disposed between the frames on which the goods are suspended. To heat the 750 cubic feet, that is required of air to 90°, supposing the external air at 40°, will require 132 feet more.

These last pipes are to be placed in an air chamber, under the drying-room, so as to heat the air to 90° before it comes in contact with the goods; and will be best made of cast iron.

As to the time this quantity of steam-pipe will take to produce a given effect, it may be stated, in general, that it will require about four minutes to steam away a pound of water from twenty-five yards of calico. To dry in double this time will require only half the quantity of surface of steam-pipe; and so of any other proportion.

For domestic purposes about one-third of this proportion of steam-pipe will be sufficient; that is, forty-five feet in the air chamber, and as much in the drying closet, for each twenty-five yards of cloth, or an equivalent surface of other matter.

The area of the pipe to convey away the steam may be proportioned by considering the rules which have been given for ascertaining the draught of chimneys. If Mr. Tredgold's opinion is taken on this disputed subject, then if the height of the pipe for carrying off the steam, measured from the centre of the heated chamber to the opening where the steam and hot air go out into the atmosphere, be twenty-five feet, the area of the horizontal section of the pipe must, for 270 square feet of surface of steam-pipe, be one square foot, and rather more than a-half.

All the passages for air will require to have about the same area.

A closet to dry linen for a family ought to have two horses, each of which should contain a sufficient quantity of linen, or other cloth, to require about an hour to dry them; when the first is about half dry, which it will be in about twenty minutes, another quantity should be put in upon the other horse. By this mode of changing them alternately there will be a considerable saving of fuel as well as of time.

For domestic purposes there will be quite as little expense in fitting up an apparatus of this kind as the most common in use. One of the boilers in the wash-house will answer as a steam-boiler, without rendering it the less fit for other purposes.

[The best and cheapest method of drying cloth in calico printing and bleacheries is in the open air. White goods never look so well when dried by artificial heat. More room is required in the former case; but the buildings for this purpose may be of the cheapest construction. In large works, however, and particularly in the winter season, the occasional use of artificial heat is often convenient, and sometimes indispensable, to despatch in business. When this is recurred to, I have already observed, that the employment of steam or stove heat may be resolved into a question of economy merely. On this

question I have also offered some remarks at the conclusion of the article "*steam heat.*" If a stove heat be employed, which I should certainly advise on the score of economy, I should recommend a stoving room of the following construction:—The building to be of brick, thirty feet wide, twenty-eight feet high, and of a length to correspond with the extent of the work to be performed: the roof of the ordinary construction, and ventilated at the top by apertures equal to one foot square for every twenty feet length of the building. The floor of the building, which is of earth, to be traversed lengthwise by two parallel horizontal flues, two and a-half feet wide, and six inches in depth; the sides and bottom of the flues to be of brick, and the top of thick cast iron plates, connected by flanges and bolts; each of these flues to be terminated by a fire-place at one end, and a chimney at the other, but in the reverse order, so that there be a chimney and fire-place at each end of the building: the fire-places to be fed on the outside: to prevent loss of heat downwards the flues should rest on shoal arches, or on bricks set edgewise, so that the air may circulate underneath. This arrangement, with two straight flues, is much preferable to the common one of having but one flue in the form of the letter U, with the fire-place and chimney at the same end of the room, on account of the liability of the latter to get out of repair from the alternate expansion and contraction of the iron plates. To obviate, in some measure, this inconvenience from expansion and contraction, some cast the plates in the form of a half cylinder, without flanges, and lap them one over another in the manner of tiles; but a straight flue, with plates joined by flanges, is preferable; and, to avoid all inconvenience from the above cause, the middle plate in the series should be bolted, or otherwise permanently fastened to the brick part of the flue, so that the plates may elongate from the centre towards each end: the terminating plate at each end of the flue should not be confined by the wall, but allowed to slide into an aperture fitted to receive it. The flues should be about one foot asunder, to allow room to pass between them. The wooden platform of bars, from which the cloth is hanged, should be suspended from the beams, and about four feet below them; or, a double row of beams may be put in in the first instance, and the cloth bars affixed to the lower row. A flight of stairs, and tackle, or wheel, should be attached to one end of the building, under a projecting part of the roof, by which the wet cloth is conveyed into the upper part of the building, and let down from the bars. The only entrances into the building are by a door at the top of the stairs, for the introduction of the cloths, the bottom of which to be on a level with the grated floor, and another at the lower part, to allow the workmen to enter occasion-

ally for repairs or examination of the flues. The lower door may also serve for ventilation when required. A row of small windows, one pane in height, and three or four in width, placed at a distance of ten or twelve feet on each side of the building, and about five feet from the ground, will afford sufficient light. It would be well to have double windows, and the sashes well cemented in, to prevent loss of heat on the one hand, and admission of air on the other. The doors should be made to shut close. A net work of wire must be suspended over the flues their whole length, and about four from their upper surface, to mark the nearest approach that the cloth can make to the flues, and to catch any piece, or end of a piece, which may accidentally fall from above.

The method of operating is extremely simple; as soon as the goods are introduced and suspended, the fires are kindled, and the doors closed; the heat is continued till the cloth is dry. The operation may require from two to three hours according to the quantity of moisture in the cloth and the heat employed. The state of the cloth can be ascertained from time to time by examination through the lower door. When the cloth is dry, the doors should be thrown open to admit the air, and expel the atmosphere of steam. The cloth must now be removed as expeditiously as possible, and, if another lot of wet cloth is not ready for drying, the doors and the apertures in the roof must be closed, by valves made for that purpose, in order to preserve as far as possible the heat accumulated in the flues and walls of the building for use at another time.

The reader will observe, that the process of drying here recommended is essentially different in principle from the one recommended in the preceding article. The object of this arrangement is to exclude as much as possible the agency of air; there is, properly speaking, no ventilation, unless the apertures in the roof for the escape of vapour be accounted such; the operation is conducted on the same principle as the evaporation of water from a steam-boiler, in which case we apply the heat at the bottom of the vessel, and make a vent at the top for the escape of steam. If we consider this drying room, (while in operation,) to represent the steam-boiler, and the moisture in the cloth the water of the boiler, the analogy is complete. The air has nothing to do with the process, and should have nothing to do with it. Mr. Tredgold's calculations proceed on the principle of making air the medium of communication of heat to the wet cloth, (instead of applying the heat immediately to the cloth itself;) which is as unnecessary, and, in fact, as absurd as it would be to attempt to evaporate water from a boiler, by heating a current of air and passing it through the water to be evaporated. Evaporation might, indeed, be carried on in this

way, but certainly with great loss of heat; for the air, which is in this case the carrier of heat, must pass out of the water at a temperature, at least, as elevated as that of the vapour formed; and of course, all that caloric which has raised its temperature from that of the atmosphere, to that of the watery vapour, is lost.

The error on this subject, which is nearly universal, both with practical men and writers, probably originated from associating the idea of drying by artificial heat, with that of drying by air exclusively. In the last case the freer the circulation of air the better, because the heat, which supplies the evaporation, is derived wholly from that source, and the notion very naturally occurred that the two operations might be economically combined; but they cannot be united, not even in the driest state of the atmosphere. If it be asked what is to expel the vapour that is formed from the drying-room when the admission of air is prevented, the answer obviously is, the same power that expels the steam from a steam-boiler; the successive portions of steam as they form must expel the preceding: at the close of the process, there will of course be an atmosphere of steam in the room, but that is driven off by almost the first gush of air, on opening the lower door.

If steam-heat be preferred on account of its greater safety, or from any other cause, it should be applied on the same principle as above recommended, merely by substituting horizontal steam-pipes for the fire-flues; the construction of the drying-room in every other respect may be the same.]

AIR-STOVES.

A current of heated air may also be made the means of distributing heat, and is a more simple and elegant mode of attaining the whole effect of the fuel than when steam is made the agent of heating.

Belper Stove.

The first person who made any material improvement in the air-stoves in England was Mr. Strutt, of Derbyshire, for the purpose of warming his extensive cotton-works more uniformly and with greater economy than formerly. The first, or most simple plan of these stoves, was, that of enclosing an iron furnace, called a cockle, in a mass of brick-work, leaving an empty space of a few inches all round it, in order to allow a current of air, admitted by passages below, to come in immediate contact with the whole surface of the iron chamber and pipe. This air, after being heated, and consequently rarefied, would naturally ascend towards the head of the stove, and pass

through one or more apertures into the room required to be warmed.

The brick-work was built of considerable thickness round the cockle of these stoves, in order to prevent the escape of heat in the immediate vicinity of the stove, and of course, to economise the fuel more effectually; as they were sometimes built in other apartments than that which is required to be heated. From the whole of the lower part of the cockle being the receptacle of the ignited fuel, it is obvious that its exterior will often be elevated to nearly the same temperature as the inside; consequently a current of air passing over its exterior surface will become heated in a proportionable degree to the rapidity of its passage.

This method of heating air is, undoubtedly, the most economical which has been hitherto devised in this country, as all the disposable heat given out by the fuel, with the exception of what is necessary to carry off the smoke, is absorbed by the air in its passage through the air chamber of the stove. And it affords a most convenient method of disseminating heat.

It appears from an experiment made with the Derby stove hereafter described, that one pound of coal will raise 5085 cubic feet, or 339 pounds of air through 59 degrees, which is equivalent to one pound of coal rising 20,000 pounds of air one degree.

In heating by steam we have, by Buchanan's calculation, in the place of 66 pounds .6, or 933 cubic feet of air, at 140° in one minute, only two pounds of steam furnished in the same time, and with the same fuel.

If the steam were all condensed and the water cooled down to the temperature of the room, it would be, doubtless, nearly equal to the effect produced by the warm air heated by the same weight of coal. But we see, from facts derived from good authority, that steam falls very short of the effect produced by making air the vehicle of heat.

In the first place, the heat lost in the conveyance of steam is much greater than that lost in conveying air. The temperature of the steam is 212°, that of the air only 130°. But the greatest difference is caused by the ratio of the surface to the solid content of the air-channel being only one 30th that of the steam-pipe to supply the same sized room.

Another source of deficiency in heating by steam, which must be very considerable, is the heat which escapes with the hot water and uncondensed steam.

The steam-pipes exposed in the rooms in which the steam is condensed are, probably, always about, but never less, than 180°. At this temperature only one half of the original steam is condensed, and, of course, they give out only half the heat

would be given out if the condensed water were allowed down to the temperature of the room. This loss, with ready stated, will go far to explain the great difference ır of warming by air.

/ithstanding the obvious advantages of air-stoves in point omy, for heating extensive cotton-mills or other manu- s, and warming hospitals, prisons, or other buildings)pen fires would either be impracticable or unsafe, the s not sufficiently made known to the public, nor its ical advantages pointed out, until it was mentioned by chanan, in his "Essays on the Economy of Fuel and ment of Heat," published in 1815. Since this period, lvester, in his very able work, "The Philosophy of ic Economy," has called the attention of the public to t importance of the question, by showing the beneficial ion of an extensive stove of this kind, erected in the nfirmary, and the Pauper Lunatic Asylum at Wake-

far preferable that the area on which a stove of this to be erected, should allow of a parallelogram subter-)assage, three times as wide as it is high, being carried ımunicating with the external atmosphere at some con- distance from the building, in order to allow of pro- ı current of cool air for the purposes of ventilation in mer season, as well as for the supply of the stove for ɜ the air of the apartments in winter. The stove lso be erected as near the middle of the area of the as convenient, and be placed, if possible, from six to eet below the floor, in order to preserve as much uni- as possible in distributing the warm air through the

represents a section of the cockle, and air-stove erected at the Der- ıry, and fig. 61, a transverse section of the air-stove, exhibiting the ırrounding the cockle, as given by Mr. Buchanan. The cockle, *a*, a cubical form, with a dome, or rather groined arch top, about three t high; and is made of plate or wrought-iron about three-sixteenths thick, riveted together like the ordinary boilers of steam-engines. ɔ passes off by a narrow passage, *b*, at the base of the cockle, into , which leads to the chimney. The brick-work, surrounding the ɔuilt with alternate openings as represented in the side view, at *f*, ight inches distant from the sides of the cockle. Through these *e*, pipes are inserted, which may be made either of sheet-iron or ırthenware, so as to extend within an inch of the cockle, by which air to be heated may be thrown near, or in immediate contact with : of the cockle if desirable; which was found by Mr. Strutt to double lerivable from the same quantity of fuel.

izontal partition of the air-chamber, represented at *d*, cuts off the ıtion between the lower and the upper portion of the air chamber. l openings in the lower half at *g*, exhibit the openings of the main ıding from the exterior atmosphere.

passing from these lower flues, *g*, through the apertures beneath the

horizontal partition, *d*, and coming in immediate contact with the body of the stove, must find its way into the upper air-chamber, *h*, through the numerous apertures or pipes in the upper division, by which circuit its velocity will be sufficiently retarded to obtain the necessary elevation of temperature from the heated cockle.

In order that the air may not be injured for the purposes of respiration, the size of the fire-room in Belper stoves must be so regulated as not to heat the cockle or body of the stove, at an average, above the temperature of 280° Fahrenheit according to Mr. Sylvester, or 250° according to Mr. Tredgold, when the air is intended to supply living rooms, but for drying-rooms more heat may be given, if the saving of time is an object, but still it is more economical to dry at a lower temperature.

From the upper or hot air-chamber, *h*, a main hot air-flue, *i*, leads to each of the floors which are to be heated. The horizontal and inclined parts of these main flues should be made of brick or stone, and if they have to pass under ground, be secured in a case. The vertical parts may be made of sheet-iron, or even well-seasoned wood.

An opening over the door of each room allows the entrance of the heated air into the several rooms; and a flue from the bottom of each room proceeds to the roof of the building, from whence the whole of the air is discharged by a turncap, the mouth of which is by a vane kept constantly from the wind.—The outlet flue in each room has also an opening near the ceiling, which is used in summer to increase the ventilation, but kept shut in winter.

When the stoves of the Pauper Lunatic Asylum at Wakefield are in full action, the air on the average moves with the velocity of five feet in a second. The area of each of the two main flues is twelve superficial feet, which gives 120 cubic feet for the quantity which passes through the whole house in every second. Supposing the cubic content of the house to be 400,000 cubic feet, the whole of the air in it will be changed in a little less than every hour.

Provided a stove of this construction is well built, and so managed as not to allow the warmed air to attain too great a temperature, it is not only much more economical than any other method for warming extensive buildings, but it is equally salubrious with the more recent mode of employing steam-pipes for this purpose, if not more so. The principal disadvantages of the plan appears to be that it cannot be easily applied to an extensive building unless constructed during the erection of the edifice. It is also difficult to give a tolerable appearance to the several parts.

As the air passages of this kind of stove ought to be placed several feet under ground, it affords also a convenient mode of admitting a portion of cold air to the interior of the building in the summer season, as well as supplying heated air in the winter.

The change in temperature of the air by passing in this way, Mr. Sylvester says, is much more than could be supposed. The cold air-flue at the Derby Infirmary is about four feet square,

Fig. 60.

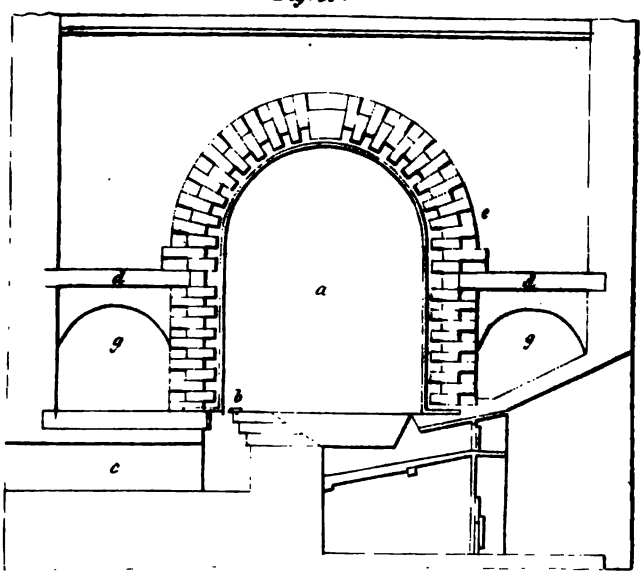
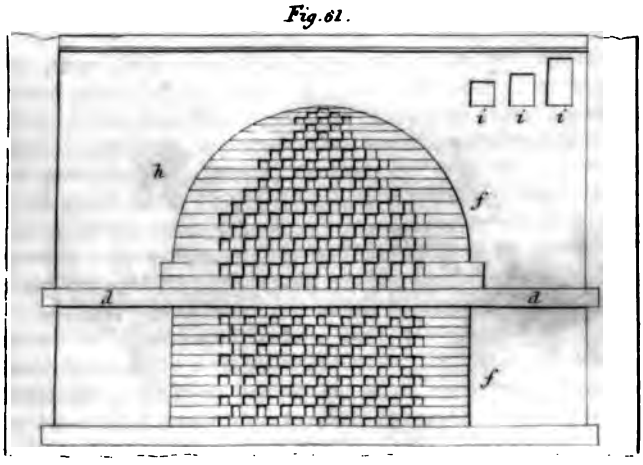


Fig. 61.



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ASTOR, LENOX AND
TILDEN FOUNDATIONS
R L

ngth seventy yards. In the month of August, when ometer in the shade stood at 80°, the air which entered e under ground at the same temperature, was found at the extremity where it entered the stove-room: the t this time was sufficient to blow out a lighted can- nother experiment, when the outer air was at 54° this duced to 51° by passing through the flue.

a great advantage of the air-stove above the use of apparatus, since this last only supplies the deficiency winter, but has no tendency to check it when that nosphere is beyond the medium temperature of the

HOT-BEDS.

ts formerly used in their laboratories another kind of pparatus, under the quaint title of balneum ventris e horse's-belly bath, being a bed of hot horse-dung; pparatus is still used in some chemical manufactories, e of white lead and verdigris, and particularly by gar- hastening the germination of seeds, or warming the which tender plants are kept.

menting substances used in forming hot-beds are sta- or dung, in a recent or fresh state, tanners' bark, trees, grass, and the herbaceous parts of plants ge-

ng is in the most general use for forming hot-beds, which are masses after it has undergone its most violent fermentation. These masses in the form of solid parallelograms, of magnitude proportioned er of vessels to be placed in them, or the size of the frames which ced on them, the degree of heat required, and the season of the h they are formed.

ation of dung-beds is effected by first marking out the dimensions which, if intended to heat garden-frames, should be six inches sides than that of the frame to be placed over it, and then by suc- s of dung laid on by the fork, raising it to the desired height, ently and equally throughout.

bark is only preferred to dung, because the substance which under- cess of putrid fermentation requires longer time to decay. Hence seful in white-lead works, and the bark-pits of hot-houses, as re- seldomer moved or renewed than dung.

on. Mr. Boyle used moist hay in his laboratory, for and putrefactions.

g is by some mixed with bark, with ashes, with leaves, saw-dust, ppings of leather, chopped spray, and such other durable sub- n be brought to ferment along with it, and prolong its duration as mass.

of leaves with stable litter is recommended, using only a little or eighteen inches deep at top, in which to plunge the pots. leaves, or leaves mixed with litter, they must always be well fer- the rank heat extracted out of them before they are made up into

Flax dressers' refuse ferments very slowly and regularly, and, used instead of stable-dung in forming hot-beds, it will keep up a steady heat longer than almost any other substance.

Oak-leaves are said to be preferable to those of any other sort. The leaves of beech, Spanish chesnut, and horn-beam, will answer the purpose very well. It seems that all leaves of a hard and firm texture are very proper; but soft leaves that soon decay, such as lime, sycamore, ash, and of fruit trees in general, are very unfit for this mode of practice.

A very considerable ground of preference is the consideration that decayed leaves make good manure; whereas rotten tan is of no value. It has been tried both on sand and clay, and on wet and dry lands, and it never deserved the name of manure; whereas, decayed leaves are the richest, and of all others the most suitable manure for a garden. But this must be understood of leaves after they have undergone their fermentation, which reduces them to a true vegetable mould. This black mould is also, of all others, the most proper to mix with compost earth.

Leaves mixed with dung make excellent hot-beds; and beds compounded in this manner preserve the heat much longer than when made entirely with dung. In both cases the application of leaves is a considerable saving of dung.

The object of preparation in all these substances being to get rid of the violent heat which is produced when the fermentation is most powerful, it is obvious that preparation must assist in facilitating the process. For this purpose, a certain degree of moisture and air are requisite; and hence the business of the operator and gardener is to turn them over frequently, and apply water when the process appears impeded for want of it, and exclude wet and damp when it seems chilled and impeded by too much water.

In winter, the process of preparation in gardens generally goes on under sheds, which situation is also best in summer, as full exposure to the sun and wind dries the exterior surface too much; but, where sheds cannot be had, it will go on very well in the open air.

A great deal of heat is undoubtedly lost in the process of fermentation; and it has been attempted to turn this heat to some account, by fermenting dung in houses or sheds, with shelves, or in vaults under rooms. The latter mode seems one of the best in point of economy, and is capable of being turned to considerable advantage where common dung beds are extensively used; but the most economical plan of any seems to be that of employing only Mc Phail's pits, or such as are constructed on similar principles; namely, by sinking a pit, considerably larger than the intended garden-bed or chamber for the chemical vessels, lining it with bricks; and then constructing, at a sufficient distance within it, an inner wall, having holes disposed chequerways to allow the heat to penetrate into the chamber that is formed by this interior wall. The dung or other fermenting substances is thrown into the space between the inner and outer walls of the pit, and being covered over with boards, or a layer of earth, the heat passes through the holes of the inner wall into the chamber, and heats the digesting vessels, which are piled up in a stack, and the chamber closes with a falling door, or it supplies bottom heat to a bed of earth, laid upon boards near the top of the chamber, just above the highest row of holes.

This is a very cleanly method of applying the heat of fer-

nenting dung or vegetable matter to chemical and horticultural purposes.

Mills' Pyrometer.

The expansion of air constituted the basis of the original hermometer by Fludd; spirit of wine and quicksilver were hen employed in preference, but Mr. Mills has returned to air. Dr. Hook found that the heat of summer expands the ordinary air about a 30th part; and Mr. Boyle, in his History of Cold, alleges his own trials, proving that the force of the strongest cold in England does not contract the air above a 20th part; so that the sum of a 20th and a 30th part being a 12th part, we may conclude that the same air which is extremely cold occupies twelve parts of a space, will in very hot summer weather fill thirteen such spaces; which is as great an expansion as that of spirit of wine when it begins to boil; for which reason, and for its being so very sensible of warmth or cold, and continuing to exert the same elastic power after being so long included, it is the most proper fluid for the purpose of thermometers.

Dr. Hales found, that when an empty retort was exposed to the fire, until its bottom was red hot, the air contained in it was expanded to a double space; and in a white heat to a triple space.

The want of an apparatus to measure the higher degrees of heat above the temperature of boiling quicksilver, more conveniently than by Mortimer's or Wedgwood's thermometers, is much felt by potters, smelters of ores, and many other artists.

Mr. Mills' instrument, as represented in fig. 62, is founded upon the expansion of air by heat, and is composed of a platinum bulb and stem, drawn out without any joint. The bulb, *a*, is hollow, and about half an inch in diameter; the stem, *b*, must be perfectly cylindrical, and about one-sixteenth of an inch in diameter on the inside.

This tube is attached, or rather soldered, by an air-tight joint, to a glass pipe, *c*, which is first bent in an angular direction, and then into the form of an inverted syphon, *c*, *d*. The upper extremity of the pipe is blown into a bulb, *d*, of the same size internally as the platinum bulb, *a*, a funnel-shaped opening being left at first for the introduction of a sufficient quantity of quicksilver; after which this opening is closed by the action of the lamp. A scale, *e*, is attached to that leg of the inverted syphon, which is farthest from the platinum bulb and stem.

When the platinum bulb, *a*, is put into the fire, the air contained within it is expanded by the heat, and pressing upon the quicksilver contained in the legs of the instrument, forces it up more or less toward the glass bulb, *f*, according to the greater or less heat to which it is exposed.

As the platinum bulb would be corroded and destroyed by exposure to the fire naked, a crucible, *g*, of very refractory clay, is used, to defend it: the platinum bulb and part of the stem is placed in it, and the remaining space filled up with powdered charcoal or sand.

It is evident that by using this pyrometer the heat of any furnace may be read off on the scale, during the whole of any

process, and a greater degree of certainty as to the administration of the fire obtained, than at present.

Lamp Light.

This is probably the oldest method of illuminating dwellings, and yet, notwithstanding the importance of the subject, the relative value of the oils, used for burning in them, has been much neglected by chemists.

Leutman, in his Vulcanus Famulans, an excellent German treatise on the heating and lighting of our dwellings, published in 1723, and which has run through repeated editions in Germany, although unknown in England, seems to have been the first that made any experiments on the duration of the burning of the different kinds of oil.

The oils he enumerates as being then those most usually burned in lamps, are olive-oil, rape-oil, linseed-oil, poppy-oil, gourd-oil, sunflower-oil, and walnut-oil; he gives the preference to olive-oil, for night lamps, and says two pounds of it will burn as long as three pounds, or three pounds and a-half, of rape-oil.

The experiments of succeeding authors confirm the superiority of olive-oil, and the principal of them are here given.

Scopoli made the following experiments on the burning of several vegetable oils, both as to the duration of the flame, and the quantity of soot that they yield while they are burning.

Half an ounce of nut-oil was three hours and four minutes in burning, and it yielded twelve grains of soot.

Half an ounce of linseed-oil was three hours and twenty-nine minutes in burning, and it yielded eleven grains of soot.

Half an ounce of olive-oil was two hours and fifty-five minutes in burning, and it yielded only one grain of soot.

Half an ounce of rape-oil was three hours and twenty-four minutes in burning, and it yielded three grains of soot.

Half an ounce of nettle tree oil, (celtis australis) was two hours and forty minutes in burning, and it yielded only half a grain of soot.

These experiments demonstrate the superiority of olive-oil, and the nettle tree oil.

The following experiments on this subject are related in Nicholson's Journal, for Nov. 1812; which show not only the quantity of oil consumed in an hour, but also the time that the lamp took to boil 2000 grains, or rather more than a quarter of a pint of water.

	Oil consumed in grains	Time of boiling in minutes
An argand's lamp	414	7
The same, new trimmed	500	6¼
The same, without the glass	.	7¾
The same, with a glass, two inches in diameter, and one inch and a half high	400	6½

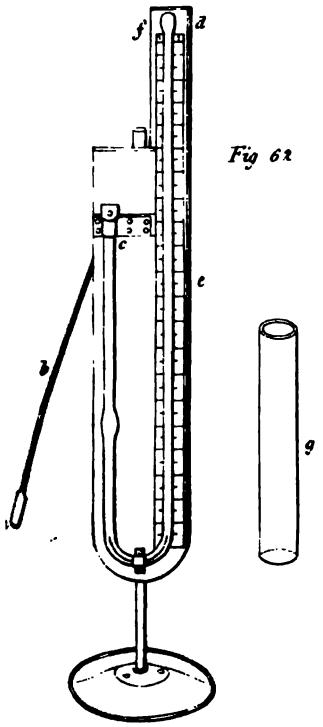


Fig 62

Fig. 63.

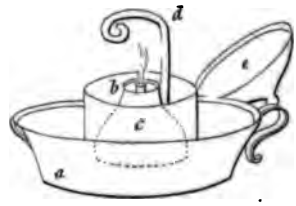
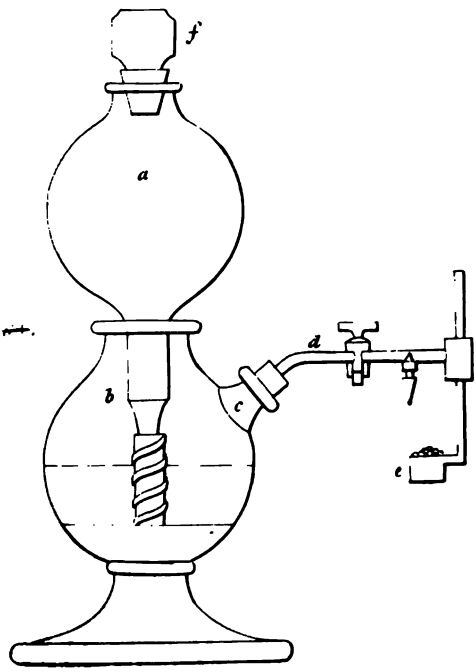


Fig.



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	Oil consumed in grains.	Time of boiling in minutes.
, with four burners of eight threads, air-tube in the centre . .	200 .	10
, with eight burners of four threads, r-tube	300 .	6½
e, with only three threads, and a wo inches wide, and one inch and high	320 .	6½
e, with a glass only one inch high	276 .	6¼
there described, with 8 burners .	. .	3½
7 .	. .	4
6 .	. .	4¼
5 .	. .	6
4 .	. .	6¾
3 .	. .	9½
2 .	very slightly in	15
1 .	only simmered in	30

, Mr. Joseph Hecker, director of the salt-works, and rator of the mines at Iruskawitz, in Gallicia, has found tha burns much better than oils of other substances, in ntaining bad air, and injures the health of the workmen

ght of petroleum is to that of German rape-oil, as 1000 .3, and to that of tallow, as 1000 is to 500.3, supposing first burns with a small flame. The quantity of nap- t for lighting the same space, is to that of tallow, as to 925.74, and to that of German rape-oil, as 1000 is 8. Coal-tar oil, which is in the same proportion as is preferable to it, being less expensive: oil of bones is ch yields the most brilliant light.

lighting of mines containing bad air, German rape-oil ow will extinguish, when naptha, petroleum, and the nes, will still burn; but naptha and petroleum are more extinguished by a slight motion of concussion in the oil of bones being, in this case, best for use.

Iecker has found that in mines where the oxygen had ed to 18.33 per cent., men are not incommoded. Ge- tallow, or German rape-oil, is extinguished in air con- not more than 18.1 per cent. of oxygen, whilst naptha of bones burn when it contains no more than 18.8 per

ns who cultivate the higher parts of science are often t in publishing minute improvements in their means rch, on account of their considering them of too slight dividually; although, when a number of them are col- ogether, their aggregated value becomes considerable.

ames Smithson observed much inconvenience from the gth of the wick of lamps, as occupying a large space in ervoir for oil, and thus requiring that it should be of

considerable size: and he has found that it is by no means necessary that the burning part of the wick should be a continuation of that immersed in the oil: it being this circumstance that occasions the long wick to be used in order that it may allow for a portion of its length to be cut off daily for the purpose of trimming, as it is called, the lamp. He finds it quite sufficient if the wick tube of the lamp merely contains a short bit of cotton wick, no longer than is just sufficient to reach nearly to the bottom of the oil; or instead of spun cotton the tube may be merely filled with cotton wool, lightly packed, to allow free passage to the oil.

To supply the burning part of the wick, a short and thick bit of wick, or cotton wool rolled up, may be placed on the top of the tube. This loose burning part of the wick receives the supply of oil from the cotton in the tube, and may be renewed as often as it clogs up with the carbonaceous residuum left by the oil on combustion. In the same manner, a very short loose ring of wick may be applied to the common wick of the argand lamps.

There are a class of oily bodies, not sufficiently solid to form into candles, and yet too thick to burn well in lamps, unless some means are used to keep them melted.

Fig. 63, represents a lamp made for the purpose of burning hog's lard, cocoa-nut oil, or any other concrete oil.

a, represents the outer pan of the box lamp; *b*, the inner pan; *c*, the metal burner, cast solid, with a hole in the centre for the wick; *d*, the wire cast in the burner, of sufficient length to be brought over the flame, which having contracted heat communicates the same to the burner, thereby keeping the animal matter, &c. in a liquid state; *e*, the cover to keep out the dust, &c. when the lamp is not in use.

Notwithstanding lamps of this kind were made and sold many years ago, Major Cochrane has taken out a patent for lamps of a similar construction.

Wax Lamps.

The use of oil for lamps, especially when a person wishes to carry one with him in travelling as a night light, is very disagreeable on account of its liability to be spilled; and the almost utter impossibility of confining oil in any kind of bottle, or lamp, by either ground or screw stoppers; and the consequent greasiness that it communicates to whatever is in contact with the vessel in which it is contained.

Some difficulties certainly occur in attempting to substitute wax for oil in lamps; but the greater cleanliness of wax gives an interest to the subject.

The great secret on which the burning of wax lamps depends, is the affording a supply of melted wax to the wick

immediately upon its being lighted; for this purpose, care should be taken that bits of wax should be heaped up in contact with the wick, so that the flame may melt it instantly.

The wicks of Mr. Smithson's wax lamps are made of a single cotton thread, waxed by drawing them through melted wax: it is supported by a burner made of a small bit of tinned plate; which has two slits cut at each end, and the middle parts raised up to form a wick holder. A cup is the only vessel necessary for a wax lamp, the wax being cut to pieces and pressed into it: when a wick is consumed it is only necessary to pierce the wax with a large pin down to the burner, and introduce a fresh piece of waxed cotton.

If the wax lamp is required to have a thicker wick, as for experiments with the blow-pipe, the wick may be made in two pieces, as for the oil lamp, and only the detached end will want occasional renewal.

The best manner of extinguishing wax lamps so as to preserve the wick for re-lighting, is to overcharge it with wax, by holding a piece so that as the wax melts it may fall on the wick, and lessen the flame, when a gentle puff will extinguish it at once without any ill smell.

These wax lamps have a superiority over wax candles in that the flame being always at the same height, it admits a vessel of water being supported over it, ready to be used for shaving in the morning; or coffee may be kept warm over it, to the great convenience of travellers by early stage coaches; while, at the same time, the wax will congeal so quickly on the putting out of the flame, that it is ready to be packed up among the baggage, or clapped into the night bag, before the traveller has finished his dressing.

Candle Light.

The use of candles for illuminating rooms is, in general, much neater than that of lamps; but those made of tallow are very troublesome, on account of the continual snuffing that they require.

This constant attention is severely felt by persons engaged in works that require mental labour: it may, however, be in some measure avoided, by placing the candle in a slanting position, so that the end of the wick may not collect the soot in the form of mushrooms, but stick out beyond the side of the flame, and be gradually burned to ashes.

As wax and spermaceti candles are made with thinner wicks, the wick is unable to support itself, and, therefore, bends to the side of the flame and is consumed, although the candle is placed upright.

To prevent, however, the liability of the tallow to overflow

and gutter away, the candle should not be placed sloping until the wick has acquired some length, from the burning of the candle in its usual upright position.

In case two candles are used on the same table, they should not be placed too nigh together, lest the tallow should grow soft by their joint heat, and the candles gutter away.

This sloping position has been long adopted for the watch candles used for night lights.

No general rule can be given for the proper slope, as this depends on the thickness of the wick, and the greater or less twist given to it.

To ascertain the effect of snuffing on the consumption of tallow in candles, six candles of the best animal tallow cast in the same mould, with wicks of twelve threads, were burned for one hour. The following are the results.

Snuffing every ten minutes.

Weight in grains when lighted.	After one hour.	Loss.
781	676	106
782	682	100
784	682	102
785	681	104
786	676	109
792.5	690	102.5

Without snuffing.

673	573	100
676	573	103
676	570	106
681	581	100
689	580	101
689	592	97

With a view to ascertain the comparative combustibility of piney tallow, a new kind of concrete oil brought from the East Indies, candles of the materials under-mentioned were cast; one mould was used for all, and the wicks were composed of an equal number of threads, except that the wick of the wax candle was made smaller. Having been accurately weighed, they were burned for one hour in an apartment in which the air was kept still, and at a temperature of 55°.

	Weight in grains when lighted.	At the end of the hour.	Loss.
Wax	840	719	121
Half wax, half piney tallow	770	631	139
Spermaceti	760	604	156
Half spermaceti, half piney tallow	777	605	152
Animal tallow	811	703	108
Half tallow, half piney tallow	792	681	111
Cape wax	763	640	123
Piney tallow	812	702	110

These experiments also show the comparative value of the most usual materials of which candles are made.

Candles were made in the same mould as before, wicks composed of twelve threads, the number used in wax candles of the size employed. It was also contrived to cast a wax candle for the sake of more perfect comparison.

The following are the results of an hour's combustion:

	Weight in grains when lighted.	At the end of one hour.	Loss.
Wax	730	594	136
Half piney tallow, half wax	750	622	128
Spermaceti	736	590	146
Half wax, half sperm	762	616	146
Piney tallow	774	684	90

Mr. John White took out letters patent for a method of making candles whose outer surface being less fusible than the interior mass, serve as a vessel to contain it. The moulds used by him for manufacturing his candles are a drawn or hollow tube. He then melts as much wax, spermaceti, tallow, or any other material or compound fit for, or adapted to, the making of candles, as is equal to fill one third of the mould, or any such quantity as may suit the fancy. When the material is poured into the mould in a fluid state, he immediately lays the mould down lengthways, and keeps it constantly going round until the material inside of the mould is fixed or congealed round the side of the mould. Thus a case or hollow cylinder will be formed from the fluid material very true, and exactly the size, shape, and length of the mould. This case, or cylinder, when discharged from the mould, forms the outside of the intended candle, which may be cottoned and filled up at pleasure, in the usual way, with some material of greater fusibility, which forms a regular candle.

The patentee avers, that candles manufactured by this means can be made to look superior to wax, and vary in price according to quality, from a little more than the price of tallow to two-thirds of the price of wax, and answer all the purposes of wax-candles, not requiring snuffing, afford equal or superior light without having a greasy appearance, and acquire a fine high polish by friction; may be used in any weather or climate without losing their solidity, polish, or beauty, and completely removes the disagreeable smell and feel arising from the use of tallow candles.

In Bavaria, they have lately adopted the use of wooden wicks; but in what their superiority consists does not appear.

Comparison of Lamps and Candles.

Count Rumford states, that the relative weight of the undermentioned inflammable substances, required to produce an equal degree of light, is as follows:—

A good wax candle, kept well snuffed, and burning with a clear bright flame,	100
A good tallow candle, kept well snuffed, and burning with a bright flame,	101
The same tallow-candle, burning very dim for want of snuffing,	229
Olive-oil, burnt in an argand's lamp,	110
The same burnt in a common lamp, with a clear, bright flame, without smoke,	129
Rape-oil, burnt in the same manner,	125
Linseed-oil, burnt in the same manner,	120

The Count would have been glad to have made another

nience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, tending to diminish the hazard of fire, and lessening the high insurance premium on cotton mills. The cost of the attendance upon candles would be fully equal to that upon the gas apparatus, and upon lamps much more, in such an establishment as Mr. Lee's.

From the brilliant manner in which our streets are lighted by gas than ever they were or could be with oil or tallow, there is a greater degree of security both in person and property for every class of honest men. Crimes cannot now be committed in darkness and secrecy; and as the risk of detection increases, the temptation to guilt is diminished, and thus coal gas, by the brilliant light it sheds in our streets, has worked and is now working a moral reformation. The housebreaker and pickpocket dread the lamps much more than the watchman; and no more efficacious measure of police was ever introduced into society than that from gas lights. But this is not all, lighting our streets and houses with gas is a new art, and gives birth to several new trades, and as these new trades have arisen at a time when the improved sense of society has discovered the injurious nature of the restrictions formerly imposed on industry, they are allowed to be freely exercised by any one. The same circumstance is common to many other newly-discovered arts, and by the practice of which numerous classes of men gain a livelihood. Already in our country the professions and the trades which are thus liberated from the apprentice law of the fifth year of Elizabeth are not a few, and they promise ere long to become the majority of professions and trades in society. One consequence therefore of these scientific discoveries and improvements, not at first expected from them, is to liberate mankind, without political convulsions, from the thraldom of the unwise regulations of barbarous ages.

At present, most of the large towns of this kingdom are lighted by gas, or are on the point of being so lighted. Several towns on the continent have also adopted the same expedient.

Although much apprehension was excited on the first introduction of gas lighting, by the large collection of an explosive gas, yet only one gasometer has been blown up since the practice was generally introduced; this took place in the infancy of the art, and was occasioned by a workman applying a lighted candle to the part whence gas was issuing and mixing with atmospheric air. A few accidents have occurred by the gas escaping from pipes, but these have also in general been owing to carelessness. Shops and apartments are not close enough to

keep gas confined, and even if they were, the quantity which can escape is too trifling, compared to the quantity of air in the apartments, to occasion any mischief. Coal gas is most explosive when mixed with about five parts of air. It would be therefore requisite in a room which contains 1728 cubic feet, lighted by a stream of gas, consumed at the rate of five cubic feet in an hour, that the burner should be left open upwards of fifty hours, before the mixture would become highly explosive. When coal gas is used, its offensive odour gives warning of its escape, so that one of its most noxious qualities is a valuable safeguard.

The following statement is given by Mr. Accum. An argand burner which measures in the upper rim half an inch in diameter, between the holes from which the gas issues, when furnished with five apertures one-twenty-fifth part of an inch in diameter, consumes two cubic feet of gas in an hour, when the gas flame is one inch and a half high. The illuminating power of this burner is equal to three tallow candles eight in the pound.

An argand burner, three-fourths of an inch in diameter as above, and perforated with fifteen holes one-thirtieth of an inch in diameter, consumes three cubic feet of gas in an hour when the flame is two inches and a half high, giving the light of four candles, eight to the pound.

And an argand burner, seven-eighths of an inch in diameter, as above, perforated with eighteen holes, one-thirty-second of an inch in diameter, consumes, when the flame is three inches high, four cubic feet of gas per hour, producing the light of six tallow candles, eight to the pound. Increased length of flame makes imperfect combustion and diminished intensity of light. And if the holes be made larger the one-twenty-fifth of an inch, the gas is not completely burnt. The height of the glass chimney should never be less than five inches.

According to Mr. Accum, one gas lamp, consuming four cubic feet of gas in an hour, if situated twenty feet distant from the main which supplies the gas, requires a tube not less than a quarter of an inch in the bore.

Two lamps, three feet distant, require a tube three-eighths of an inch.

Three lamps, thirty feet distance, require a tube three-eighths.

Four lamps, at forty feet, one of a half inch bore.

Ten lamps, at one hundred feet distance, require a tube three-fourths of an inch.

And twenty, at one hundred and fifty feet distant, one inch and a half bore.

Oil Gas.

Gas for lighting rooms has also been obtained from various kinds of oil; and the comparative advantages of illuminating by gas, produced from oil and from coal, is thus stated by Mr. Ricardo. The gas produced from oil is much purer, and contains a much greater illuminating power than that from coal. The quantity of light produced from a given portion of oil gas is stated, by an eminent chemist, to be equal to three times the quantity produced from coal gas: from the result of Mr. Ricardo's experiments it is equal to four times; for he has found that an argand burner, giving a light equal to six candles, six in the pound, consumed only one cubical foot in the hour.

Mr. Accum states, that an argand burner of coal gas, giving a light equal to three candles, eight to the pound, consumes two

cubical feet per hour. Then as one foot of oil gas is equal to six candles, and two feet of coal gas are required to equal three candles, it follows, if the candles were given of the same size, that one volume of oil gas is equal to four of coal in illuminating power. If we take the mean of these statements it will be as one to three and a half; that is, twenty cubic feet of oil gas will give as much light as seventy of coal gas.

Oil gas requires no purification; it contains no sulphuretted hydrogen, which is one of the admixtures of coal gas, and of this all the purification to which it is submitted cannot wholly deprive it. The coal gas, therefore, acts upon all metallic substances, and, in a course of time, must seriously injure the pipes through which it passes; and its accidental escape in shops and houses must prove highly detrimental to all ornamental gildings, paintings or any thing of which metal forms a part. This cannot happen where oil gas is used; for it contains no sulphuretted hydrogen, and it is well known to have no action on metals whatever.

It may be said, that the mode adopted for purifying coal gas effectually deprives it of this noxious gas; but experience has proved that this is not the fact, as in many places the smaller copper pipes show evident marks of being strongly acted upon, the bore being gradually filled up with sulphuret of copper.

Hence the smaller bulk and greater purity of oil gas will allow of its employment in dwelling-houses without its producing the least inconvenience. If the pipes are well fitted together and properly proved before the gas is admitted into them, no annoyance whatever need be apprehended. Even if a cock should be accidentally left open and the gas allowed to escape, it may be immediately remedied, without leaving so unpleasant a smell as that arising from the similar escape of coal gas. It must, however, be confessed, that this inodorousness of whale oil gas may, in some cases, assist in causing accidents, which would have been guarded against if coal gas had been used; for, as its presence is not detected by its smell, if a cock be left open it may mix with the air of a room, and reach the exploding point without discovery, an event which could not happen with coal gas.

Some kinds of oil gas, however appear to contain sulphur, for in Paris there is a company for lighting by gas, which uses the rape oil obtained from the seeds of the Brassica oleracea arvensis of De Candolle, and it has lately been found that the sulphur contained in this seed was dissolved in the gas, and had a pernicious effect on the neighbourhood where it was consumed. The gas attacked metallic substances and affected respiration. The brass burners were soon corroded and destroyed, and filled with an efflorescence, which has been analyzed and shown to be

a sulphate of zinc and copper, a sub-sulphate of copper, phosphate of copper, and oxide of iron, with some accidental traces of silica. This shows the necessity of washing the gas thoroughly, and of not using these seeds, if the washing will not clean the gas.

In consequence of oil gas giving, in proportion to its bulk, a much greater quantity of light than coal gas, it has been compressed into strong iron vessels, easily portable, and our houses and drawing-rooms may now be illuminated by lamps that never need snuffing, sputter no grease, spoil no clothes, make no dirt, and never give a single spark. They may be carried about without danger, and if turned over or let fall, neither spill oil nor tallow. In general, they are not yet adopted, because people adhere to old practices and hate novelties; but ultimately they will come into use, and we shall be saved both dirt and trouble, and risks of fire will be diminished. In the lamps with which the London portable gas company engage to supply their customers, the gas is compressed into one-thirty-second of its usual volume.

It has been customary to consume oil gas with the same sort of burners as coal gas, which causes a considerable waste, and gives rise to a mistaken idea of the quantity of light given out by each gas. The argand burner, which admits the gas through a number of small holes, is the best species for perfect combustion, but, which would hardly have been imagined, it is found that these holes should be nearer together and smaller for oil gas than for coal gas. In any case they should be only so far apart that the flame from each should just coalesce with that from the next. The gas produced from oil contains more carbone than that from coal; the light is in proportion to the quantity of carbone, and the same sized holes which completely consume the carbone of the coal gas do not burn all that of the oil gas. It is, consequently, necessary that burners for oil gas should be made with smaller holes, and these holes should be closer together than those for coal gas. Hence oil gas is unfit for street lamps, as it is much more liable to be blown out by the wind.

The illuminating power of oil and coal gas has, however, been differently stated by different persons. According to some, the power of the oil gas is as three and a half times that of the coal gas; whilst, according to others, it is only two, and even not so great. On this question, however, turns one which is of very great importance, whether oil or coal gas works are most advantageous. Dr. Fyfe, in a paper in the Edinburgh Journal, first throws doubts on some experiments of Mr. Ricardo's and of other gentlemen, on account of their having been incorrectly made, while he seems disposed to admit the accuracy of the experiments of Messrs. Herepath and Rootsey, which do not give

so high an illuminating power to oil gas. Mr. Dewey's experiments, published in the Annals of Philosophy, and which showed a great degree of illuminating power in oil gas, were made, it appears, as well as some other experiments, with coal gas of a very small specific gravity, only 406, and Dr. Fyfe contends, that the illuminating power of both gases, after being properly purified, is in proportion to their specific gravity. The oil gas Mr. Dewey used was 939, which is very good, and if a good oil gas is only three and a half times superior to a very inferior coal gas, its superiority must be much reduced when brought into competition with the latter when of an equal good quality.

Dr. Henry proposed to ascertain the illuminating power of each gas by the quantity of oxygen necessary for its combustion, and tried by this test he obtained the following results:

One hundred volumes of coal gas, of the specific gravity,	took of oxygen
345	78
500	166
620	194
630	196
650	274
One hundred volumes of oil gas of the specific gravity,	**took of oxygen**
464	116
590	178
753	220
906	260

From this it appears that the best oil gas is to the worst coal gas, as three and a half to one, while the best of both stand in the relation to one another of 26 to 21.

On the theory that the olefiant gas contained in both is the principal source of light, as this gas may be condensed by chlorine, Dr. Fyfe proposes the condensation as a measure of the illuminating power of each. The mixture, however, must be excluded from the light, to prevent any action on the carburetted hydrogen.

The following method for trying this experiment is proposed by Dr. Fyfe. A graduated jar, inverted in a water trough, must be filled with fifty measures of the gas, fifty measures more of chlorine must then be introduced, the tube being covered with a paper shade, to prevent any action on the other gases. In the course of from ten to fifteen minutes, the condensation will be completed, and as the chlorine and olefiant gases combine in equal proportions, the diminution in the mixture will indicate correctly the quality of olefiant gas in the gas subjected to trial.

This experiment, in Dr. Fyfe's opinion, promised to be an accurate mode of ascertaining the comparative illuminating powers, and by this method he has found the oil gas, prepared in Edinburgh, to be to the coal gas, as thirty-one to seventeen, or nearly eighteen to ten. Dr. Fyfe admits that the other con-

stituents of both gases, possess some illuminating powers, and unless the proportion of these other ingredients are the same in both, and, consequently, his method is only an approximation to the real proportions; but he suspects coal gas will be found to possess, or, at least, may be made in general to possess, about half the illuminating power of that from oil. He has found this to be the case with those made in Edinburgh, by producing the same quantity of light, and marking the quantity of gas consumed.

SPECIFIC GRAVITY.

The apparatus for determining the densities or specific gravities of bodies is very simple, but of the greatest use in determining the proper strength of the solvents to be employed in processes, or the time when operations are to be stopped; as also for investigating the purity of substances.

Hydrostatical Balance.

For solid bodies, or gross fluids, the hydrostatical method of determining specific gravities is the best: the balances used for this purpose must be very good, and one of their scales made to take off, and have its place supplied by a piece of thick wire, or a cylindrical rod, with a hook at each end, which is of sufficient weight to counterpoise the scale that is left at the other end of the beam.

The first consideration is the apparatus to enable the chemist to weigh the substance first in the air, and then when sunk under water. This apparatus may be either a single horsehair or fine silver wire for such solid bodies as can be supported by tying them to it; or a net of the same materials for globular bodies; or a small glass bucket for powders, quicksilver, or other heavy liquids that remain at the bottom when put into water, and do not dissolve in it.

The apparatus being determined, and fixed to the hook of the balance, is to be counterpoised and the weight noted, the subject to be examined is then added, and exactly weighed. The difference between their weights is of course the weight of the substance in air.

A tumbler, or other vessel, of distilled, or rain water, is then brought under the apparatus, and the substance sunk in the water. If it is apt to imbibe that fluid, it is left in the water for some time, and then the water being removed, the substance is wiped, weighed again, and the quantity of water absorbed noted.

The substance is then weighed while under water, care being taken that no bubbles of air adhere to its surface, nor to

any part of the apparatus, which might buoy them up and render the weight false.

Finally, the substance being removed, the suspending apparatus used is counterpoised while under water to the same depth as before; and its weight noted.

The difference of these two last weights is the weight of the substance in water.

Now, as substances weighed in any liquid lose therein the weight equal to that of the liquid whose room they occupy, it follows that the difference between the weight in air and that in water, is, so far as is sufficient for practical uses, the weight of the volume, bulk, or cubic content of the water displaced by the substance: and, consequently, the ratio or proportion between the weight of the substance itself in air and that of the water it displaces, when weighed in water, shows the proportion of its relative weight or specific gravity in respect to that of an equal bulk of water.

Thus taking Mr. Boyle's example,—

Weight of a piece of marble in grains, 1169.

Weight, when under water, in grains, 738.

Loss of weight, being the volume or bulk of the piece of marble, in grain-measures of water, 431.

Then as 1169 is to 431, so is the specific gravity of marble to that of water; and of course, as it is usual to consider the specific weight of water as a standard, and call it unity, or 1, the proportion will be, as 431 is to 1169, so is 1 to a fourth number sought, whence as unity does not multiply, by simply dividing 1169 by 431, the required number is found, namely, 2.712, which is the specific gravity of the specimen under examination.

But of the solid absorbed water, then it is plain that although the preceding mode of calculation will give the apparent specific gravity, yet, in order to know the specific gravity of the solid parts of the body which do not admit water, it must be considered that the bulk of the water displaced, as measured by its weight, is not merely that lost on weighing the body in water, but only the difference between that loss and the weight of water it absorbed.

Weight of a dry piece of free-stone,	*a*,	1000, in grains.
Weight after soaking some time in water,		1050
Weight of water absorbed,	*b*,	50
Weight when under water,		460
Loss of weight, being the volume of the water displaced, in grain-measures,	*c*,	540
Apparent specific gravity, produced by dividing, *a*, 1000 by *c*, 540, is		1.801
Difference between the loss of weight, *c*, and the quantity absorbed, *b*,	*d*,	490
Real specific gravity, produced by dividing, *a*, 1000 by, *d*, 490, is		2.040

If the solid is lighter than water, and does not dissolve in it, the apparatus must have a heavy body attached to it to make the subject of the experiment sink in the water.

The specific gravity of liquids is determined hydrostatically by weighing a convenient solid body, that is not soluble either in water or the liquid, as a piece of glass, first in water and then in the liquid whose specific gravity is sought. For if the loss of weight in water be divided by the loss of weight in the liquid under examination, the quotient will be the specific gravity of the latter.

If the solid body to be examined is soluble in water, it must be weighed first in air, and then in some liquid which does not dissolve it, and its specific gravity determined in respect to this liquid. The specific gravity of that identical parcel of liquid must then be determined as just mentioned, and then the two specific gravities, namely, that of the solid in respect to the liquid, and that of the liquid itself in respect to water being multiplied together, the product will be the specific gravity of the solid in respect to water: for as the specific gravity of liquid used, is to that of water, so is the specific gravity of the solid in relation to that liquid, to its specific gravity in relation to water.

In all hydrostatical experiments, the temperature of the liquid, and of the air, as also the atmospheric pressure, as determined by the barometer, should be recorded; and as far as possible, the trials should be made at a uniform temperature and pressure, as a variation in these elements will make a very sensible variation in the determination of the specific gravity if attempted to be taken to any nicety.

It is indeed true, that it is possible to reduce the specific gravities taken at any temperature and pressure to any other desired temperature and pressure, provided the expansion of the subjects under examination by heat are known or investigated; but the calculation is long, and the very sight of the algebraic formulas, given by mathematical writers for this purpose, would appal a very great majority of practical chemists.

There are some other propositions relating to specific gravity which require to be mentioned.

If the weight of any body be divided by its specific gravity in relation to water as unity, the quotient will be the weight of a quantity of water equal to it in bulk; and, therefore, if this quotient be again divided by the weight of water which any assigned measure will contain, this second quotient will be the measurement of the body in that particular measure, however irregular may be its figure, or however difficult it might otherwise be to measure it.

If the bulk, volume, or admeasurement of any body be ex-

pressed by the weight of water which is equivalent to it, then this weight of water being multiplied by the specific gravity of the body in relation to water as unity, will give the weight of the body, supposing that a person has not the conveniency or power of weighing it.

When two bodies are chemically combined with one another, the bulk or volume of the compound is not equal to that of their joint bulks; being either greater or less; as is shown in the familiar experiment of gradually adding tea-spoon-fulls of salt or sugar to a wine-glass of water, which is so far from running over, that it actually fills the glass less than before the addition of the salt or sugar, so that the specific gravity of the compound is greater or less than the mean, as the compound either contracts or expands by the union.

The amount of the expansion or contraction is calculated in this manner, taking for an example, an experiment of Mr. Hatchett.

He melted eighteen pennyweights ten grains of gold with one pennyweight ten grains of copper, and found the specific gravity of the alloy to be 17.157.

Now, the weight of the gold, 412 grains, being divided by its specific gravity 19.172, gives for its bulk or volume twenty-three grain-measures of water .05. And in like manner the weight of the copper, thirty-four grains, being divided by its specific gravity, 8.895, gives for its bulk, or volume, four grain-measures of water .27. So that the joint bulk was twenty-seven grain-measures of water .32—The weight of the mixed metals, 480 grains divided by its specific gravity 17.157, gives for its bulk or volume twenty-seven grain-measures of water .98; so that an expansion of .66 of a grain-measure of water, or 66-2732th, of the whole mass, being rather more than the 1-41th part, took place in this alloy.

If instead of the mean volume, the mean specific gravity that any mixture ought to have, supposing no expansion or contraction was to take place, is desired, it may be found by dividing the sum of the weights of the ingredients, in the above experiment, 480 grains, by the sum of the volumes, 27 grain measures .32, the quotient 17.569 is the specific gravity sought; but the comparison of this calculated specific gravity with that found by experiment, namely, 17.157, does not, at least to mere practical men, give so clear an idea of the expansion or contraction occurring in the admixture of the two bodies, as the quotation of the volumes.

Statical Examination of Gross Bodies.

There is another mode of investigating the specific gravity of solid bodies and liquids, which is sometimes more convenient than that by the hydrostatic balance.

For this purpose, there is required a wide-mouthed stoppered ttle, that will admit the solid bodies intended to be examined enter it; and whose stopper has a fine groove cut in it, by a :, along its length, that it may be put in when the bottle is ed to the brim with water, and allow the superfluous water pass out by this groove.

In the examination of solid bodies, they are to be first weighed, d if they absorb water, weighed again in their wet state. The ttle is then weighed by itself, and afterwards being filled with ter, a fresh weighing takes place; lastly, the solid is put into water in the bottle, and the joint weight taken. From these ments the specific gravity of the solid, and its bulk or vo- ne, is easily determined. For if the weight of the solid is ided by the weight of the water it displaces out of the bot- , the quotient is its specific gravity; and if the weight of the ter it displaces be divided by the weight of water that is ivalent to any species of measure, the quotient will be the neasurement of the body in that species of measure.

The examination of liquids in this method is more simple; bottle is first to be weighed empty, then when filled with ter, and, lastly, when filled with the liquid under examina- n; the weight of the liquid that the bottle holds being di- ed by the weight of the water, gives the specific gravity.

Homberg's Areometer.

The areometer of Homberg, described and figured in the m. del Ac. Roy. des Sc. for 1699, is still the best instru- nt of this kind, for the examination of liquids.

is a bottle of very thin glass, with two necks, as shown in fig. 64, which are rn out to such fineness, that a single drop of water may occupy the length bout half an inch in them. One of these necks is longer than the other, dilated at the mouth like a small funnel; and each of them has a fine mark le nearly on a level with the top of the shortest.

he weight of water that this areometer holds being ascertained and noted n, then when it is filled with any other liquid, up to the marks, and the ght of the liquid ascertained, by dividing the weight of the liquid by the ght of the water, the quotient is the specific gravity of the liquid.

he exact quantity of water, or liquid, to fill it to the two marks, is adjusted dding, or taking out, a small quantity by the point of a fine hog's bristle, in some very corrosive liquids, by a fine thread of glass.

he use of the second short pipe is to let the air escape, as the liquid is red into the areometer by the long pipe.

Thousand-grain Bottle.

or conducting this experiment with greater facility, a specific gravity bot- s now usually sold under the name of a "thousand-grain bottle," together a weight which is an exact counterpoise for it when filled with distilled er at 60° Fahr.

is a glass bottle with a slender neck, and is furnished with a ground coni- stopper, in the side of which there is a notch, or indentation, by which the rator is enabled to put in the stopper after the vessel has been completely d, the redundant fluid escaping through this groove. Unless such a con-

trivance were adopted, it would be difficult to fill a bottle with liquid without enclosing some bubbles of air.

This instrument, consequently, does not require the aid of any computation, but is simply filled with the fluid to be examined, and placed in one scale of the balance, while its counterpoise is placed in the other. If the contained fluid be lighter than water, it will appear deficient in weight, and as many grains must be added to the scale that contains it, as may be sufficient to restore the balance. This shows at once, that the specific gravity of the fluid in question is less than the standard, and, consequently, that it must be expressed by a fractional number; but should the fluid be heavier than water, the bottle will preponderate, and weights must be put in the opposite scale, when their amount must be added to that of the standard.

For example, if the bottle were filled with sulphuric ether, it would require 261 grains to be placed in the same scale to restore the balance, and, consequently, its specific gravity would be expressed thus, 0.739. Had it been filled with sea-water, which is rather more dense than that which is distilled, 26 hundredths, or rather better than a quarter of a grain, must have been added in the opposite scale, and which, as already explained, must be added to the standard, 1.000, to express the specific gravity of such water, which would be stated thus, 1.026. Sulphuric acid, again, being still heavier, would, in like manner, require 875 grains, and must accordingly be expressed as 1.875.

Cubical-inch Bottle.

Another very similar contrivance is that called the cubic-inch bottle. This is a bottle which exactly holds a cubic inch, when the stopper is in its proper place, and is very convenient, and frequently used for readily ascertaining the absolute gravity in a cubic inch of different liquids.

These two last contrivances are, however, expensive, very seldom exact, and more adapted for amateurs than real practical chemists.

Dr. Richard Davies, in Phil. Trans. for 1748, has given a large collection of the specific gravities of different bodies, from various authors, and partly from his own trials on a collection of materia medica made by Signor Vigani, and preserved in the library of Queen's college, Camb.

Brisson has since extended this list, in his Pesanteur des Corps.

Mr. Heidinger is publishing a very accurate list of the specific gravity of mineral substances, for the purpose of using it as a characteristic of them.

All tables of specific gravities ought to be accompanied with the cubic expansion of the several substances by heat, as this is absolutely necessary to reduce the expressions from one temperature to another.

Baumé's Hydrometer for Salts.

There are two hydrometers which were brought into use by Baumé, a chemical manufacturer at Paris, which are of easy construction, a point to which Baumé was particularly attentive in all his apparatus.

Fig. 65, represents the hydrometer for saline fluids, which is adjusted for use by Baumé in the following way:—The instrument having a piece of paper on which the scale is to be marked put in the stem, is first immersed in pure water at a temperature of 18.75° Reaum. equal to about 50° Fahr. and loaded with quicksilver dropped into the lower bulb till it sinks so low that only the very top of the stem was out of water, and which point was previously marked both on the paper and the stem as the 0 of the scale. The instrument is then removed to a solution of common salt, containing fifteen parts by weight of salt to eighty-five parts of water, and the height to which it floats marked on the stem as 15° of the scale. The paper being then taken out, the interval between these two points of immersion is marked on the scale as 15°, and it is extended to 75°, or any required number, merely by marking them off with compasses. The paper with the scale is then replaced in them, fixed in its place

a very minute piece of soft wax, and the end of the stem sealed at the

umé considered, therefore, that every degree of the instrument indicated sity of liquid equal to that of a solution of common salt, in which the er of parts of salt in one hundred parts, by weight of the solution, was to the same number on the scale at which the instrument floated.
t as the diameter of the stem is seldom equal throughout, he proposes to ly the incorrectness produced by this circumstance, where greater accus required, by immersing the instrument successively in solutions cong 5, 10, 15. per cent. of salt, and making these points as 5, 10, 15, &c. e scale, or, to be still more accurate, all the individual degrees may be l by actual experiment.
fact, even where the stem of the instrument is perfectly cylindrical, this l be the only way to ensure perfect accuracy, as a division of equal dis s on the scale would not precisely correspond with an equal increase of uantity of salt in the solution. But this accuracy is hardly necessary, as se of a hydrometer is at the best an imperfect approximation to the true fic gravity.
e scale of this instrument does not properly extend higher than about 30°, s is the point of saturation of water with salt, but it may be lengthened easure by marking off equal distances on the scale.
e following table of correspondence between Baumé's hydrometer for and the actual expression of specific gravity, has been calculated by Drs. mans, Driessen, Vrolik, and Deiman, the committee for compiling the macopœia Batava. The temperature of the liquor being from 56 to 60° of enheit's scale; for as no two of these hydrometers are found to agree acely together, although they are sufficient for ordinary use, there is no ocn to be more particular in noting the temperature.

Baumé.	Specific gravity.	Baumé.	Specific gravity.
0	1.000	32	1.286
1	1.007	33	1.298
2	1.014	34	1.309
3	1.022	35	1.321
4	1.029	36	1.334
5	1.036	37	1.346
6	1.044	38	1.359
7	1.052	39	1.372
8	1.060	40	1.384
9	1.067	41	1.398
10	1.075	42	1.412
11	1.083	43	1.426
12	1.091	44	1.440
13	1.100	45	1.454
14	1.108	46	1.470
15	1.116	47	1.485
16	1.125	48	1.501
17	1.134	49	1.526
18	1.143	50	1.532
19	1.152	51	1.549
20	1.161	52	1.566
21	1.171	53	1.583
22	1.180	54	1.601
23	1.190	55	1.618
24	1.199	56	1.637
25	1.210	57	1.656
26	1.221	58	1.676
27	1.231	59	1.695
28	1.242	60	1.714
29	1.253	61	1.736
30	1.264	62	1.758
31	1.275	63	1.779

Baume	Specific gravity.	Baumé.	Specific gravity
64	1.801	70	1.946
65	1.823	71	1.974
66	1.847	72	2.002
67	1.872	73	2.031
68	1.897	74	2.059
69	1.921	75	2.087

Baumé's Hydrometer for Spirit.

The hydrometer for spirit, of Baumé, is constructed exactly on the same principle as the hydrometer for salts, and the mode of graduation is also the same; that is, by solution of salt, and not by mixtures of spirit and water of different densities.

Fig. 66, represents this hydrometer, in which the zero is placed not at the top of the stem, and at the point to which the stem sinks in distilled waters, but at the bottom of the stem, and at the point to which it sinks in a mixture of ten parts of salt and ninety of water. The interval between this point and that of distilled water is divided in the scale into 10 degrees, and this scale is continued upwards by measuring simply equal portions by the compass. The tenth degree of the spirit hydrometer corresponds with the 0 of the hydrometer for salts.

The correspondence between Baumé's hydrometer for spirit and the real expression of specific gravity has also been calculated by Drs. Brugmans, Driessen, Vrolik, and Deiman, the committee for compiling the Pharmacopœia Batava. The temperature of the liquor being from 56 to 60° of Fahrenheit's scale, for as no two of these hydrometers are found to agree accurately together, although they are sufficient for ordinary use, there is no occasion to be more particular in noting the temperature.

50	0.782	36	0.847	22	0.925
49	0.787	35	0.852	21	0.929
48	0.792	34	0.858	20	0.935
47	0.796	33	0.863	19	0.941
46	0.800	32	0.868	18	0.948
45	0.805	31	0.873	17	0.954
44	0.810	30	0.878	16	0.961
43	0.814	29	0.883	15	0.967
42	0.820	28	0.889	14	0.974
41	0.823	27	0.895	13	0.980
40	0.828	26	0.900	12	0.987
39	0.832	25	0.906	11	0.993
38	0.837	24	0.911	10	1.000
37	0.842	23	0.917		

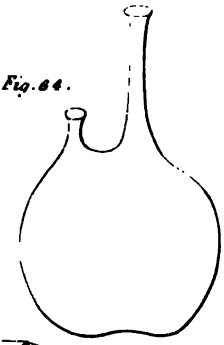
Fahrenheit's Hydrometer

In the preceding hydrometers, the investigation is conducted by simply observing the depth to which the instruments sink in the liquid that is tried.

Fahrenheit, in the Phil. Trans. for 1724, introduced another class of them, which are always sunk to a mark made on their stem, by means of weights, and which are susceptible of much greater accuracy

Fig. 67, represents Fahrenheit's hydrometer, which consists of two hollow glass balls, *a*, *b*, joined by a long slender tube, *c*; the upper larger ball, *a*, has at its top a short tapering pipe, *d*, on which a mark, *e*, is made about the middle of its height; the pipe is spread out at top like a funnel. The hydrometer is bal-

Fig. 64.



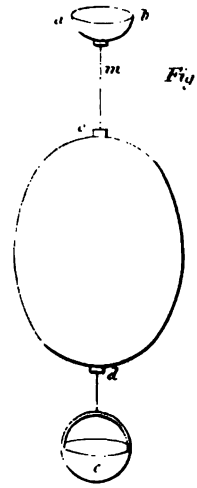


Fig. 68.

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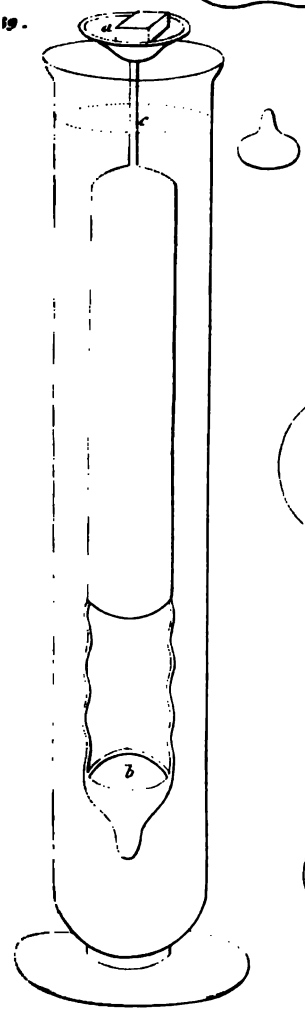

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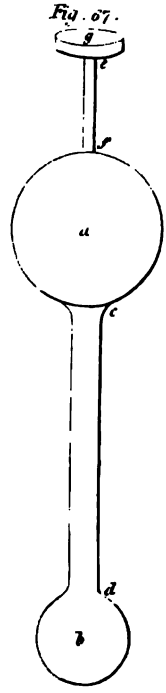

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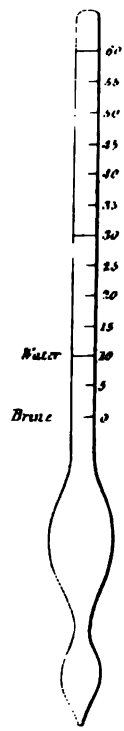
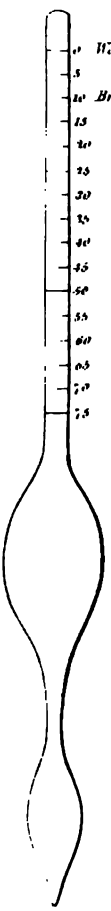


Fig. 65.



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lasted by adding a little quicksilver, so as to cause it to sink in spirit of wine nearly to the mark; and it is then hermetically sealed, and carefully weighed.

Thus prepared it is fitted for the investigation of the specific gravity of liquids. For which purpose, let it float on distilled water at any assigned temperature, and add weights to sink it to the mark: the weight, added to that of the instrument, is the weight of the water which the instrument displaces. Proceeding in the like manner to find the weight of any other liquid that the instrument displaces, this latter weight, divided by that of the water, gives the specific gravity.

M. Deparcieux used a hydrometer of this kind to investigate the specific gravity of the waters of a number of springs in France: but in order to increase its sensibility he augmented the size.

His bulb was a bottle, the bottom of which was left convex to prevent the air from lodging below. This bottle was about eight inches long and two in diameter; and was ballasted with shot. It was stopped by a well-varnished cork, in which was inserted a brass wire about thirty inches long and one-twelfth of an inch in diameter; to the top of which was fixed a small cup for the weights. The whole instrument weighed about twenty-three French ounces one-fourth.

A vessel of tin-plate, about three feet long and three inches in diameter, was used to hold the waters examined, to the edge of which was attached a rule divided into inches and parts.

The instrument was so sensible that a single grain placed in the cup made it descend half an inch, or one-seventeen thousand four hundred and twenty-eighth part of the bulk of the water displaced.

Nicholson's Hydrometer.

The hydrometer invented by the late Mr. Nicholson, is an alteration of Fahrenheit's hydrometer, to render it capable of ascertaining the specific gravities of solids as well as of liquids.

Fig. 68, represents this instrument; *a*, is a hollow ball of brass or copper; *c*, is a dish affixed to the ball by a short slender stem, *d*; *c*, is another dish affixed to the opposite side of the ball, by a kind of stirrup. The stem, *d*, is best made of hardened steel, one-fortieth of an inch in diameter, and the dish, *c*, is so heavy as, in all cases, to keep the stem upright when the instrument is made to float in any liquid. The ball is so large as to require the addition of one or two ounces in the upper dish, *b*, to sink it in distilled water, at the temperature of 60° of Fahrenheit's thermometer, so that the surface shall intersect the middle of the stem, *d*; and let both this weight and that of the instrument itself be accurately determined.

If it be required to find the specific gravity of any liquid which has no action upon the metal, immerse the instrument therein, and by placing weights in the dish, *b*, cause it to float, so that the middle of its stem, *d*, shall be cut by the surface of the fluid. Then as the known weight of the instrument added to the weight required to sink it in water, is to the same known weight added to the weights used in producing the last equilibrium, so is the weight of a quantity of distilled water displaced by the floating instrument to the weight of an equal bulk of the fluid under consideration. And consequently, the first weight divided by the second, will give the specific gravity, as in Fahrenheit's instrument.

Again, if it be required to find the specific gravity of a solid body weighing less than the weight required to sink the instrument in water, place the hydrometer in distilled water, and the body in the dish, *b*, then make the adjustment by adding weights in the same dish; subtract this weight from that required to sink it in water, and the remainder will be the weight of the body in air. Place now the body, in the lower dish, *c*, and add weight in the upper dish, *b*, till the adjustment is again obtained. The weight last added will be the loss the solid sustains by immersion, and is the weight of an equal bulk of water. Consequently the specific gravity of the solid, compared with water, is found by dividing its weight in air, by the loss it sustains by immersion.

As the cylindrical stem of this instrument is only one-fortieth of an inch in diameter, the instrument will rise or fall nearly one inch by the subtraction or addition of one-tenth of a grain. It will, therefore, indicate changes in weight less than one-twentieth of a grain, or one-sixty-two thousandth of the whole; which will give the specific gravities correct to five places of figures.

M. Charles added to this hydrometer a contrivance for inverting the lower basin by a hook to its bottom, by which it hangs, when the solid whose specific gravity is required is lighter than water. In this case, the basin is inverted, and the solid presses upwards against its bottom, and, of course, the hydrometer requires less weight to sink it.

Another person, for the purpose of investigating the specific gravities of light woods, added a spike to the fork of a stirrup; on which they may be stuck.

Guyton de Morveau's Gravimeter.

Guyton's gravimeter is another alteration by the celebrated chemist, M. Guyton de Morveau, of Fahrenheit's hydrometer; it is made of glass, and carries two basins, like the hydrometer of Nicholson. The bulb is cylindrical, and is connected with the upper basin by a slender stem, in the middle of which is the fixed point of immersion. The lower basin, which terminates in a point, contains the ballast, and is attached to the cylinder by two branches. The cylinder in M. Morveau's own instrument was six inches .85 in length, and 71 hundredths of an inch in diameter. The upper basin carried an additional weight of 115 grains.

To this apparatus M. Guyton added another piece, called the ballast piece, which is a lump of glass equal to the additional weight of 115 grains, added to the weight of the volume of water displaced by this ballast piece. This ballast piece is always placed in the lower basin when it is used; and, of course, the gravimeter will sink it to the same mark on the stem, whether it is loaded with the constant weight of 115 grains in the upper basin, or with the ballast piece in the lower basin.

Fig. 69, represents the gravimeter; *a*, the lower basin; *b*, the upper basin; *c*, the point of immersion, marked on a thin piece of glass in the inside of the stem marked *x*; the piece called the ballast piece, which is placed in the lower basin, *a*, when experiments are made on fluids of greater density than water. The gravimeter is placed in a cylindric vessel filled with water, in which it floats immersed to the mark *c*, by means of the additional constant weight, *d*. It is convenient to choose a vessel of such a depth that the instrument may be at liberty to float at the level of the mark, or even beneath it, without its being possible that the bottom of the upper basin should ever descend to the surface of the water.

A paper is pasted on the inner surface of the cover of the case in which this instrument, from its fragility, must always be kept, to show the weight of the gravimeter with or without the additional ballast piece and the volume of water it displaces in either case; as these are often required to be accurately known.

This instrument may be used for solids or fluids. It is, in fact, the hydrometer of Nicholson, from which it differs in no respect, except being made of glass. The only condition requisite for using it will be, as in his instrument, that the absolute weight of the body to be examined shall be rather less than the constant additional weight, which, in Morveau's own instrument, was 115 grains.

For liquids of less specific gravity than water, the instrument, without the additional weight above, weighed about 459 grains when of the dimensions

before laid down. It would be easy to alter this weight to the utmost accuracy, if it were requisite. We have, therefore, the range of one-fifth of buoyancy, and, consequently, the means of ascertaining all the intermediate densities, from water to the most highly rectified spirit of wine, which is known to bear, in this respect, the ratio of eight to ten with regard to water.

When liquids of greater specific gravity than water are to be tried, the constant weight being applied below by means of the ballast piece, which, in M. Morveau's instrument, weighed about 138 grains, the instrument can receive in the upper basin more than four times the usual additional weight, without losing the equilibrium of its vertical position. In this state it is capable of showing the specific gravity of the most concentrated acids.

It possesses another property common to the instrument of Nicholson, namely, that it may be used as a balance to determine the absolute weight of such bodies as do not exceed its additional load.

The object of this instrument is to ascertain, 1st. The specific gravities of solids, whose absolute weight is less than 115 grains; 2d. Of liquids inferior to water in specific gravity; 3d. Of liquids of greater specific gravity than water; 4th. The absolute weight of bodies below 115 grains; and, 5th. The rarefaction and condensation of water in proportion to its bulk, the purity of water being previously known.

In order to find the specific gravity of any solid by this instrument, place the solid in the upper basin, and add weights till the instrument sink to the fixed point of immersion in water or any other convenient liquid. Subtract these weights from the constant weight of 115 grains, and the remainder is the absolute weight of the solid. Multiply this by the specific gravity of the fluid, and note the product. Place the solid in the lower basin and add weights in the upper basin till the instrument sink to a fixed point of immersion; and subtracting these additional weights from the additional weights when the body was in the upper basin, the remainder will be the loss of weight by immersion. Divide the reserved product by this loss of weight, and the quotient will be the specific gravity of the solid with regard to the specific gravity of the liquid in which it is weighed.

In order to find the specific gravity of a fluid, first immerse the gravimeter in the fluid, and having observed the weight which is necessary to sink it to the fixed point of immersion, add this weight to that of the gravimeter; then to the weight required to sink it in distilled water, add also the weight of the gravimeter. Divide the first sum by the second, and the quotient will be the specific gravity of the fluid.

The additional or ballast piece to be placed in the lower basin when liquids heavier than water are examined, requires some attention to make it perfectly agree with the constant upper weight as to the immersion of the instrument. But this object may, by careful adjustment, be attained with the utmost certainty and accuracy.

The glass is first brought to the proper form by grinding, and afterwards carefully diminished until, when placed in the lower basin of the instrument, its immersion in distilled water at the intended degrees of temperature and pressure shall be exactly the same as when the instrument is floated in the same liquid with its constant additional weight of 115 grains in the upper basin only.

By this means there is a certainty of acquiring the utmost degree of precision at first trial; because the whole process is reduced to the mere adjustment of a weight.

Areometrical Beads.

It has been long customary to use the floating of a new-laid egg, or of a piece of amber, to ascertain when brines were boiled down sufficiently for crystallization.

The late Dr. Wilson, professor of astronomy in the University of Glasgow, proposed to measure the specific gravities of fluids by a series of small glass beads, or hollow balls, differing

from each other in specific gravity. When any of the beads are thrown into the fluid, all those that are heavier than the fluid sink to the bottom, while those that are lighter float upon the surface.

The areometrical beads have been brought to a very high degree of perfection by Mrs. Lovi. They are now used by many of the first distillers and practical chemists, and have been honoured with the highest approbation of some of the principal manufacturing chemists.

These beads are fitted up in boxes, containing different quantities, according to the purposes for which they are wanted; and they are always numbered to every two units in the third place of specific gravity; for example, 920, 922, 924, &c.

If they are required merely for spirituous liquors, thirty beads will be sufficient; but if they are required for all fluids, from ether to the most concentrated sulphuric acid, three hundred at least will be required. As these beads are marked with their respective specific gravities, we have only to throw a parcel of them into the fluid till we find the one that stands in the middle of the liquid, without either rising to the top, or sinking to the bottom. The number marked upon this bead will indicate the specific gravity of the fluid. The beads are accompanied by a sliding rule, and a thermometer for making the corrections for differences of temperature, and for finding the strength of the spirits, in the language of spirit dealers and excise officers.

The superiority of this hydrometer to every other is very great, but it is proportionably expensive. If, however, the ordinary hydrometer meet with any accident, it is incapable of being repaired; but if any of the areometrical beads are broken, they can easily be replaced, and the specific gravity may be determined with sufficient accuracy, if one, or even two, beads of the series are destroyed.

In using these areometrical beads for the purpose of determining when saline solutions have been boiled down, or otherwise concentrated to a proper point, Mr. Loudon has adopted the use of two beads, one rather lighter than the proper specific gravity of the liquid when fit for use, and the other rather heavier. If both sink, the liquor is not yet brought to the proper point; and, on the other hand, if both float it is too strong: the proper strength being when one floats and the other remains at the bottom.

[*Twedale's Hydrometer.*

This instrument is in form and principle the same as Baumé's hydrometer for salts, except in the graduation. It takes cognizance only of liquids whose specific gravity exceeds that of water. Its zero is water at 60°, and the space between that and 1.850 (formerly regarded as the specific gravity of concentrated sulphuric acid,) is divided into 170 equal parts. It is in almost universal use among the practical chemists and calico printers, and bleachers, of Lancashire, and throughout the north of England, Scotland, and Ireland; and on that account has been adopted in the articles on calico printing and bleaching, and several others in this work for facility of comparison with the experience and formulæ of English workmen and manufacturers. I

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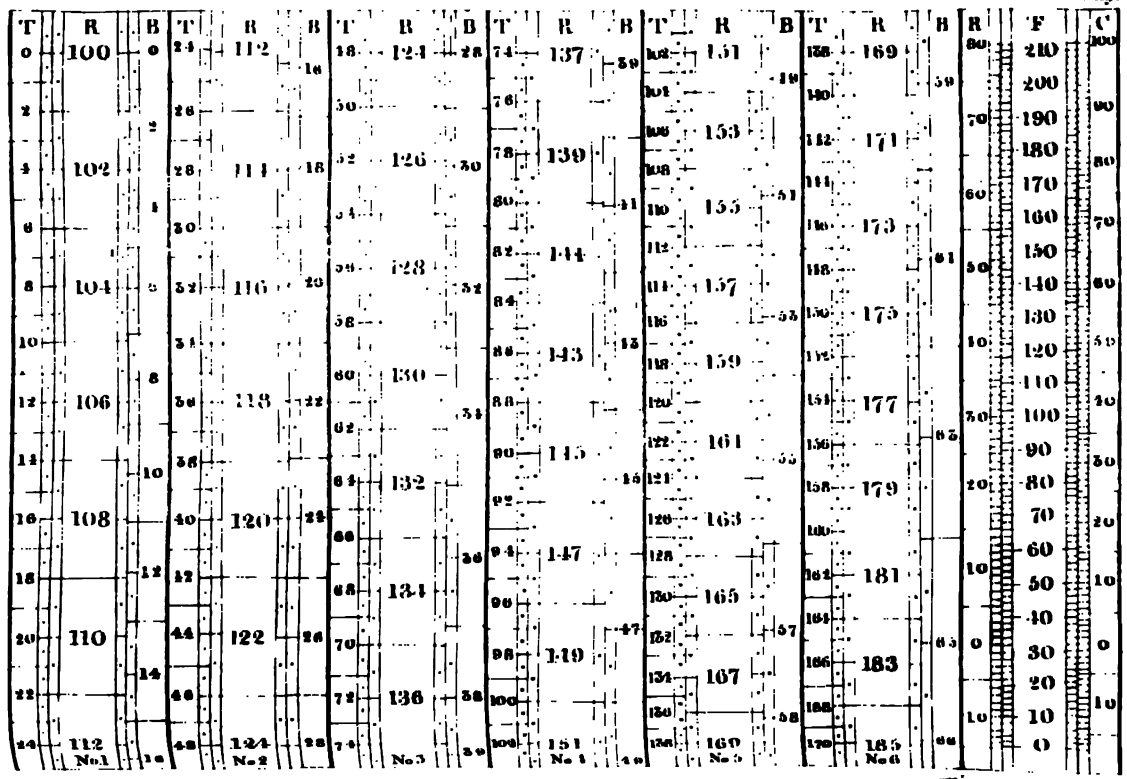
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have said that the space between the specific gravity of water and 1.850 is divided into 170° or equal parts, but this is on the supposition that the stem is of an equal calibre throughout, which, however, is rarely the case and cannot be trusted; every degree, or, at least, every ten degrees, should be ascertained by actual experiment. The general methods of procedure for this purpose have already been explained.

Rouchetti's Hydrometer.

Mr. Rouchetti, a philosophical instrument maker of Manchester, has introduced another hydrometrical scale, which is a good deal used by the calico printers, and has the advantage of its indications being easily converted into either Twedale's, or the common scale now universally adopted by scientific men, which assumes water to be 1.000 at 60° Fahrenheit. He commences his graduation with 100, which he assumes to be the specific gravity of water, and divides the space between that and 1.1850, into 185 equal parts. If we multiply the two right hand figures by 2, the product will give the degrees on Twedale's scale; if we consider the two right hand figures on Twedale's scale as decimals, his column corresponds exactly with that, which reckons water as 1.000 except that it wants the third decimal figure, which is not required in the operations of the arts. The following table shows the correspondence between Twedale, Rouchetti, and Baumé's scales. The three last columns have no immediate connexion with this subject, but will be found convenient to the practical chemist, as showing the correspondences also in the indications of Reaumur, Fahrenheit's, and the Centigrade thermometers; the first in general use in France, the second in England and America, and the latter in Germany and the north of Europe.] See the appended Table.

PULVERIZING APPARATUS.

Pounding is one of the most common methods of dividing solid substances into smaller particles. The chemist must therefore be provided with mortars of different kinds, glass, wood, iron, steel, marble, siliceous stones, and porcelain ware, with their respective pestles. The nature of the substance which the chemist has occasion to pound, must direct him in the choice of one mortar in preference to another. He must have glass mortars for rubbing together corrosive saline substances; while, for bruising succulent herbs, roots, and other recent vegetable substances, which do not require trituration, mortars made of box-wood, or oak, may be used.

It is scarcely necessary to observe, that in order that the matter may be properly subjected to the effect of the pestle, the bottom of mortars must be of a concave form, and the side

should neither be so inclined as not to allow the substance operated on to fall to the bottom, between each stroke of the pestle, nor so perpendicular as to collect it too much together, and to retard the operation.

The larger kinds of cast-iron mortars, commonly called laboratory mortars, are always provided with wooden covers, to prevent the finest and lightest parts from escaping, and to defend the operator from the effects of disagreeable or noxious substances. But these ends are more completely attained by tying a piece of pliable leather round the pestle and round the mouth of the mortar. It must be closely applied, and at the same time so large, as to admit the free motion of the pestle. In some instances it will be even necessary for the operator to cover his mouth and nostrils with a wet cloth, and to stand with his back to a current of air, that the very acrid particles which arise may be carried from him.

To lessen the manual labour, the pestle of large mortars is fastened to the end of a flexible wooden pole, which is fixed by its other end to the roof, in a horizontal position, by the elasticity of which the pestle is lifted up again to the proper height after the stroke is made; and the operator has only to direct and impel the downward stroke.

Steel mortars are used for breaking into smaller pieces, very hard but brittle substances, such as the hard stones, called gems: these mortars differ in their form from all the others, being cylindrical; and the pestle is of the same form, fitting very close, and when used struck by a hammer.

Bronze mortars, with iron pestles, are the best for general purposes; the toughness of the metal, and it not being liable to rust, rendering it superior to iron.

As to brass mortars and pestles, they are only fit to pound spices and sugar for kitchen use, where their bright gold-yellow colour renders them greater favourites than the bronze.

White marble mortars, with pestles of the same, are the best for powdering salts, as they preserve the whiteness of the powder: they are also the only mortars in which fine white emulsions can be made: but the same mortar or pestle ought not to be used for both purposes.

Dark-coloured marble mortars, with hard wooden pestles, are the best for beating together gummy and pasty substances, as they allow the operator to give a heavy stroke, without fear of breaking the mortar; and as these substances usually stain the marble, the mortars are rendered less disagreeable than when white marble is used.

Larger mortars of this kind, or even of wood, with wooden pestles, are employed for bruising pulpy vegetables, or beating them up with sugar, or similar substances.

Glass mortars, with glass pestles, can only be used for rubbing together powders, and dissolving them in cold liquids.

Wedgewood-ware mortars, with pestles of the same ware, are equally unfit for powdering hard bodies, but, from their roughness, are superior to glass for rubbing powders together, and allow hot liquids to be poured into them.

Agate mortars, with pestles of the same, are, of course, very small, and totally unfit for powdering; but they are used for grinding the hardest powders, such as those of stones for analysis, glasses for enamelling and glass painting, and the harder earthy and metallic colours for painters. The pestles of these mortars are sometimes fixed in a wooden handle, so as to resemble a hammer.

It should always be remembered, that when a very hard body is ground to powder, the friction wears the mortar as well as the substance pulverized; consequently, for delicate experiments, it is necessary to weigh the powder before and after the process, and to allow for the increase of weight by what has been abraded from the mortar.

Mortars, as will be seen hereafter, are still used on a very large scale in the mine-works, and my grandfather and father, who, for some time, were the only makers of flour of mustard seed in or near London, used numbers of them in a horse-mill, until a manufacturer at Staines began to grind it with stones, sometime about 1780; soon after which, the present compound powder, formed of mustard flour, capsicum, turmeric, salt, and wheat flour, was introduced in the place of the genuine mustard.

FILTERING APPARATUS.

The most usual process for clarifying fluids consists in filtering them; but this operation cannot be performed without the aid of intermediate substances, the very minute pores of which suffer only the fluid to pass through them: an infinite variety of substances are used as instruments of filtration, paper, flannel, linen, earths, pounded glass, charcoal, porous stones, &c. all of which may be usefully employed.

Paper Filters.

Paper is known to be a kind of web formed of vegetable fibres that have undergone various preparations. The particles of these fibres are intermingled in such a manner as to leave between them pores, the tenacity of which is always proportionate to the state in which the paste was at the moment it was converted into paper.

The great art is to choose paper, the pores of which have precisely the size requisite for admitting only the fluid that is to be filtered, but none of the particles that impair its transparency.

Two sorts of paper are met with which produce this effect, and though they are not always so perfect as might be desired, they are those which have hitherto been preferred, as having but little size in their composition. The one is white, the other is a kind of gray paper.

The liquids that have been filtered through white filtering paper, are always transparent; but it has the inconvenience of breaking very readily, and its pores are soon obstructed, so that the filtration goes on but slowly.

The gray paper can serve for a greater length of time to furnish also clear liquids, but as the size with which it has been manufactured, has not been so well purified as that of the white filtering paper, it always communicates to the liquids a disagreeable taste, which proceeds from the solution of the foreign substances contained in this paper. This is also the reason why certain fluids, such as whey, wine, spiritous compounds, and other potable liquids, that have been filtered through gray paper, have always a smell and a taste, which are easily recognised by an accurate taster. Hence it proceeds that, amongst these liquids, some are more susceptible of spoiling than when they have been filtered through white filtering paper.

The nature of the paper demands most attention when saline solutions are filtered. If gray paper is used, it often happens that a part of its substance is dissolved by their action, so that the filtered liquid is not so pure as we should wish to have it. This inconvenience, which is not so perceptible when white paper is used, may be still more diminished by the precaution of not employing filters till after they have previously been washed several times with boiling water. A chemist ought always to keep a store of filters washed in this manner.

M. Josse has remarked that whey, clarified and filtered through white paper, could be kept in good preservation for more than a fortnight, when filtered every day; which was not the case with the ordinary gray paper, even though previously washed.

By a diametrically opposite effect, other vegetable juices have been rendered transparent, and kept in good preservation, without passing into the acid state, by filtering them every day through gray paper; it has only been observed that their colour became more intense during the first days, and that they afterwards gradually became colourless.

In order that a filter of paper may produce its full effect, it is necessary that it should not adhere too closely to the funnel which supports it, otherwise the filtration would soon be interrupted. This inconvenience is avoided by folding it different ways, but as these folds soon become deranged, some prefer placing straw or glass tubes between the filter and the funnel, but the folds made in the filters, produce as much effect as the straw and tubes. Funnels grooved on their inner surface are very commonly used for this purpose.

There is a far superior contrivance which may be applied, as well to the greatest as smallest quantities. It is an earthen cullender, made of a size proportionate to the business intended to be performed by it, and very full of holes, which ought to be also of a larger bore, than in the sort intended for household purposes. The cullender of the largest size must not, however, exceed what a sheet of filtering paper will well cover; for any greater magnitude than that would become useless. With these must be had also a glass funnel, whose mouth is broader than the cullender, and a stand, by which the cullender may be supported over the funnel. Where this kind of filter is not used in the intention of purifying any liquid body, but for separating a sediment, or precipitated powder, from some superfluous fluid, or when the liquid is of an alkaline nature, a linen cloth, of the size of the paper, must also be procured, and placed under it. By this apparatus, all the ends of filtering may be answered with great ease and expedition.

Very large glass funnels next suit this purpose best, provided the paper be supported in the hollow of the funnel, with a little cotton lightly thrust into the hollow. But this method is much more precarious, as well as slower than the other; and the paper, if not good, or if used with fluids of a relaxing quality, is very subject to break during the operation, and thereby frustrate all that has been done.

When a very small quantity of precipitate is to be collected, and its weight

accurately determined, the paper being cut of a proper size, is held before the fire, and, when sufficiently heated, is rubbed with tallow, except a small round space in the centre, which is to form the point of the filter when folded. The filtration being finished, that part of the precipitate which has settled on the side of the filter, is washed down by a fine stream of water, or other proper liquid, from a funnel, or syringe, until the whole is collected at the point.

Flannel Filters.

Flannel filters are much in use; they are made in the form of a cone, the base of which is kept open by means of a hoop, which is afterwards fastened to a frame, or hook, with strings. This species of filter is termed the Hippocrates' sleeve; it is used for filtering spiritous compounds. As it may be made very capacious, it is able to receive a large quantity of liquid at once, but it passes through very slowly, and it is often necessary to wait for a long time before the liquid passes through clear, on which account these filters ought never to be used, unless when others are not fit for the purpose.

When syrups are to be filtered, instead of giving the flannel the form of a bag, the cloth is merely fixed upon a square frame, to which it is attached, at its four corners, by means of pegs. The boiling syrup is poured upon the middle of it, which almost always bags a little, and often, at the end of a few minutes, the liquor passes through very clear.

The filter thus disposed, may also be employed for filtering any other liquids, especially such as are of a watery nature, and which do not contain potash or soda in solution, for, were they never so slightly alkaline, the filter would be soon destroyed, and the filtered liquid rendered impure.

Cotton Filters, or Tow.

Carded cotton is reserved for filtering such fluids as are considered precious, whether on account of the difficulty of procuring them, or of the small quantity with which one is provided.

In order to form this filter, carded cotton or tow is introduced into the throat of a glass funnel, and stuffed in with a cane glass, so that it forms a kind of slightly compressed cork; the fluid which is to be filtered is then poured into the funnel. The filtration takes place drop by drop, and after the first drops have been separated and poured back again, those which follow are always clear. The essential oils may very conveniently be filtered by this means without danger of waste.

Filtration through Glass.

The acids, especially those that are in a concentrated state, can only be filtered through pounded glass; but this substance must not be used till it has been washed several times; at first, with a large quantity of water, and afterwards with an acid, in order to deprive it of the earthy or other foreign particles that might be dissolved by the acids which are to be filtered.

These filters are formed in a funnel. The great art that is required, in order that they may produce this effect, is, first, to fix some fragments of glass in the throat, afterwards to add other smaller fragments, and thus to continue always diminishing the size of the fragments, till a thickness of three or four inches has been formed; the upper layer of which ought to be glass reduced to fine powder.

This kind of filter lets the liquid pass through with sufficient facility, so that in less than an hour it is possible to filtrate several pounds of acid in a glass funnel of a moderate size.

Clarification.

The clarification of liquids, simple as it may appear to be, nevertheless merits particular attention, especially when we consider the advantages which are obtained from it in the chemical and pharmaceutical arts.

Clarification by Rest.

Clarification by rest is sometimes subject to several inconveniences, the chief of which are, that it requires a considerable length of time, and that during this interval the formation of new products often takes place.

A very striking example of what happens in this case, is the spontaneous clarification of the juices of plants or fruits. These juices, when fresh expressed, are always turbid: they nevertheless become clear by imperceptible degrees, but then their nature is no longer altogether the same.

Clarification by Egg, or gelatinous Substances.

The effect of the albuminous and gelatinous matter is principally remarkable in the vinous liquids. It is on this account that they are employed when it is required to fine wines, and other fermented liquors; that is to say, when we wish to give them that high degree of limpidity which they can rarely acquire and preserve by mere repose. In this case, nothing more is required than to dissolve eggs, isinglass, hartshorn shavings, or any similar substance, in a small quantity of the liquid, and to mix this solution, cold, with the remainder. A short time after a kind of net-work is observed throughout the whole mixture, which, soon contracting together, collects all the foreign substances from the fermented liquor, and carries them with it to the bottom of the vat.

In other instances, it is necessary to heat the liquids with which the eggs are mixed, and it is only at the moment of ebullition that the clarification takes place: most of the foreign made syrups are clarified by this process, and no other has yet been discovered that produces a better effect.

It is also observed, that egg alone is not always sufficient to clarify liquids, even though they are raised to a degree of temperature sufficient to make them boil, but that it is necessary to assist its operation by means of an acid, or a salt with a redundance of acid. In proof of this, may be adduced what takes place in the clarification of whey; for it is only when there is added to this fluid at the moment when it begins to boil, some cream of tartar or vinegar, that the egg with which it had previously been mixed, coagulates, and carries with it the cheesy matter, which impaired the transparency of the whey.

It is absolutely necessary to separate the magma which forms in liquors that are clarified with egg, especially when in order to concentrate those liquids, it is necessary to evaporate them by the aids of ebullition. Without this precaution this magma would dissolve, and these liquors would become more turbid than they were previous to the clarification. It proceeds from a similar cause that broth, from which the scum has not been taken off, always retains a disagreeable appearance and will not keep.

Though the employment of albuminous matter for clarifying the juices of certain vegetables be of utility, it is however not without its inconveniences. Amongst others, one that has been remarked is, that it changes the nature of these fluids in such a manner as partly to destroy their medicinal properties. It often happens to certain pharmaceutical preparations, such as decoctions of medicines, that, when in order to clarify them, recourse has been had to white of egg and heat, they are almost without effect, unless we take care to double the proportions of the ingredients that ought to enter into their composition. Dr. Lewis has even remarked, that this operation deprived the syrup of white poppies of all its powers.

Clarification by Cream.

New cream is employed with advantage for clarifying spirituous liquors, one or two spoonsful to the pint are sufficient to produce this effect in the space of

a few hours in the cold. But as in this clarification, some cheesy matters always remain suspended in this fluid, by reason of their great tenuity, it is necessary to separate them, at last, by filtration through a flannel bag, or through paper.

Clarification by Heat.

There are some fluids which, in order to become clear, require to be subjected to a degree of heat nearly approaching that of boiling water. These are principally such as are rendered opaque merely by substance, the solubility of which cannot become complete unless it be facilitated by raising the temperature of their solvent above its natural state. Many saline solutions stand in this predicament, and whoever occupies himself ever so little with chemistry will frequently meet with such.

Most of the fresh expressed juices of vegetables may also be partially clarified by the operation of heat. Thus it is customary amongst foreign apothecaries to have recourse to this means with those juices which, on account of their thickness and viscosity, are not susceptible of being filtered.

Frequently a slight degree of heat applied to the expressed and filtered juices of certain vegetables is sufficient suddenly to destroy their transparency; in this case a flaky whitish substance floats in the liquid, and collects at the bottom of the vessel. This is the substance which Rouelle, the younger, considered as the vegeto-animal matter of corn, but which Parmentier demonstrated, in 1772, to be a substance analogous to the white of an egg.

Granulation of Metals.

The malleability of metals renders it impracticable to reduce them to smaller particles by the mortar or similar means; chemists are therefore obliged to adopt other methods.

Filing is frequently adopted, but in the case of iron the filings rust very quickly, and spelter clogs the files so that they cease to act: hence the shavings of these metals obtained in turning them in a lathe are usually obtained from the manufactories.

Gold, silver, and copper, are granulated by melting them, and pouring them in a fine stream from a height of several feet into a vessel of water. Lead is also reduced in this manner into very small thin fritters, by holding a small iron ladle, having one or more pin holes in its bottom, three or four feet above a pail of water, and pouring the melted lead into the ladle.

Both lead and tin are granulated by pouring them, when melted, into a wooden box rubbed on the inside with chalk, then quickly covering the box, and shaking it briskly, the concussion of the metal against the sides of the box at the moment of fixing, reduces it to a fine powder, from which the chalk is afterwards washed off.

The perforated ladle and granulating box are consequently necessary instruments in a metallurgic laboratory, as also a pair of rollers, a wire-drawing machine, anvils and hammers of various sizes.

HEATING APPARATUS.

The greatest part of this apparatus is so well known, that little need be said of it.

For ordinary purposes copper caldrons and skillets are used; but those of bronze or bell-metal are to be preferred, and for some particular purposes, it is necessary to have not only tinned copper, but also pewter vessels of this kind, as well as cast-iron kettles of various sizes, and iron ladles.

The best earthenware vessels for this purpose are the brown Nottingham ware, or those made of stone-ware. There are sometimes to be met with in the eastern parts of London, Dutch stone-ware jugs, the originals from which the patent mustard-pots have been copied, but much coarser in their appearance: these Dutch jugs bear the fire so well that they may be used for years to boil liquids. When elegance is studied, the Wedgwood-ware may be used.

The glass vessels used for this purpose, are glass capsules, which are generally supplied by cutting out the bottom of matrasses, boltheads, bodies, and retorts which have been used, or are accidentally broken.

Uncut bodies are, of course, used for merely heating large quantities of liquids in glass: if they are to be steamed away, the body is cut, to present a larger surface to the air.

Boltheads of platinum have been recently introduced for boiling certain metals in oil of vitriol, in order to dissolve them.

For digestions in glass, the matrass, or bolthead is used, and to prevent the loss of the volatile matter as much as possible, the neck of the matrass is left long, and is either closed by a bladder pierced by a pin which is left in it, or, as advised by Glauber, by a stopper formed of pewter, for which a glass stopper loaded with a weight may be substituted, or, according to the same excellent practical chemist, by luting on it a bent glass pipe, in which a little quicksilver is placed to serve as a moveable stopper, an apparatus which has been recently re-invented under the Gallic name of a tube of safety, or in plain English, a safety-pipe. Sometimes two matrasses are joined mouth to mouth, and luted together, the vapour that condenses in the upper vessel drips into the lower, and as it thus circulates, the apparatus is called a circulatory, and the operation itself is called circulation.

As it is difficult to get out any residuum from a matrass or even a bolthead, Dr. Lewis used a receiver, and luted to the mouth of it a narrow mouth adopter, which served as a neck.

Matrasses are sometimes made with the bulb oval instead of being spherical; these oval matrasses have generally a very long and slender neck, and are called philosophical eggs for digestions.

Apparatus for melting and calcining Bodies.

When solid substances are to be exposed to intense heats to fuse them, or to favour their mutual chemical action, the ves-

sels, generally employed, at least for experimental purposes, are called crucibles.

The Hessian crucibles, which are manufactured only in Great and Little Almerode, and from hence exported all over the world, will support an intense heat for many hours, without softening or melting; but they are disposed to crack when suddenly heated or cooled. This inconvenience may be, on many occasions, avoided by using a double crucible, and filling up the interstices with sand, or by covering the crucible with a lute of clay and sand, by which mean the heat is transmitted more gradually and equally. These, which give a clear sound when struck, and are of uniform thickness, and have a reddish brown colour without black spots, are reckoned the best. The Saxon crucibles, particularly those of Waldenburg, are also highly esteemed, but not exported.

The Stourbridge clay skittle-pots are not baked, but merely dried; they have a very clumsy appearance, but bear a very intense heat.

Wedgwood's crucibles, made of porcelain clay, are very excellent for all experimental purposes in the small way. They are very smooth within, and stand a very strong heat. They should be covered with some coarse clay before they are exposed to the action of a very intense heat.

The black crucibles, formed of clay and blacklead, were formerly imported from Ipser in Germany, as the Dutch bought up all our blacklead; but are now made in England. Dr. Leigh says, several clays wrought together with powdered blacklead and horse-dung, make good crucibles; so that he seems to have been the inventor of them. The Sheffield crucibles of this kind are made of clay and powdered coke.

These crucibles are very durable, resist sudden changes of temperature, and may be repeatedly used; but they are destroyed when alkaline or saline substances are melted in them, and suffer a partial combustion when exposed red hot to a current of air; they answer best for melting metals. On account of these blacklead pots bearing the fire so well, and their being easily cut by a saw, or bored with a gimlet, Dr. Lewis used them for making portable furnaces.

Blacklead pots are in sizes, the largest being marked one hundred, which are about thirteen inches and a half deep on the inside, and ten inches and a half at the mouth. The next sizes are marked ninety, eighty, seventy, &c. without any intermediate numbers. They are generally about half an inch narrower one than another, though not with any exact regularity. Number sixty is about twelve inches deep, somewhat less than eight inches wide at the mouth, and six inches and a half at the middle of the height. These pots will generally fit into the second size above it, by means of sawing off some of the thick part of the bottom, and rasping off the edges; as eighty into one hundred, seventy into ninety, or sixty into eighty: the interval may be filled up with slaked lime mixed up with as much water as will render it sufficiently fluid to be poured in between them.

Macquer extols the Dutch pots in which their butter is exported, as the best crucibles known in Paris; they may perhaps be made of the same ware as has been already mentioned.

Iron crucibles are made, but seldom used; they are intended for melting the alkalies, either by themselves or with earthy substances.

Platinum crucibles and capsules, on account of the nearly absolute infusibility of the metal by the heat of chemical furnaces, and its unalterability by most agents, are of the greatest service in many cases. They should always be put into a common crucible to defend them from the direct action of the coals, the clinkers of which affix themselves to the sides and bottom with so much obstinacy that they cannot be detached without risk of injury to the vessel. But platinum is acted upon by nitrate of potash in fusion, and also by alkalies; and hence these crucibles cannot be used for the fusion of substances containing them.

Crucibles of perfect pure silver are particularly useful in chemical operations, for the fusion of earthy bodies with alkalies for which platinum vessels cannot be employed; but the utmost degree of heat they can bear is a moderate redness; and the metal acquires a crystalline texture by cooling, and is

extremely breakable, so that they must be frequently re-cast; for which purpose, the chemist ought to have a mould.

Calcining dishes are made of ordinary crucible ware, and are sold in the warehouses; but there are two other vessels of this kind which are always made by the metallurgic chemist himself, namely, the scorifying or clay test, and the bone-ash cupel or test, for which purpose he must have moulds of wood or brass.

These moulds are merely rings of brass or box wood, strengthened by an iron hoop, and are narrower at bottom than at top. The materials of which the cupels and tests are made being rolled by the hand into a ball, are put into the mould, and pressed down by a kind of brass-headed pestle, which fits accurately into the wider extremity of the mould, and would enter about one-third of the depth of the ring. The lower surface of this pestle is flat, with a projection in the centre, being a segment of a sphere, and thus forming a similar cavity in the upper part of the vessel.

The mould for clay tests is about three quarters of an inch deep, two inches wide at top, and an inch wide at bottom; the spherical projection at the head of the pestle, is an inch and a half wide, and rises three-eighths of an inch; the pestle enters a quarter of an inch into the ring. Fine washed Stourbridge clay, or any other equally refractory clay, mixed with the powder of the same clay, previously violently heated, and which is generally obtained from the upper part of crucibles that have been used, is put into the ring or mould, which has been slightly greased, and the pestle struck with a heavy mallet to render the test very solid. A circular piece of wood or card of a proper size, is then used to push out the test, at the wider end, which is then dried for use.

The cupel mould is about the same depth, an inch wide at top, and three quarters of an inch at bottom: the spherical projection on the head of the pestle is half an inch across, and rises a quarter of an inch: the pestle enters a quarter of an inch into the ring. The bone ash being sifted, but not with too fine a sieve, and moistened with water, is first pressed into the mould by the pestle in the same manner, and then dried for use.

Ash tests are made in a coarser manner by merely pressing into an iron ring, moistened bone ash, or wood ash, from which the salt has been extracted by elixiviation, and scooping a cavity in the upper surface; these tests are left in the ring.

SUBLIMING APPARATUS.

When only those volatile substances that are solid are collected by the chemist, the operation is called sublimation.

The name bolthead is given to a spherical glass vessel, flattened a little at the bottom, and provided with a short thick neck, in which respect it differs from a matrass, the neck of which is long and slender.

In order to sublime any substance, a part of the globe of the bolthead is sunk into a shallow sand-pot, as deep as the matter which is to be volatilized as the heat rises. In this manner it is that corrosive sublimate, calomel, camphor, and other similar products, are formed for the purposes of commerce; the neck of the vessel is loosely stopped with a little tow, but the entire stoppage of the neck, as it would endanger explosion, is guarded against by occasionally thrusting a wire down the neck.

The heat is most commonly applied through the medium of a sand-bath, and the degree of heat, and the depth to which the vessel is buried in it, are regulated by the nature of the product; but very often the bottom of the bolt-head is coated with clay, and thus exposed to the naked fire, by being hung in a pot-furnace in place of the sand-kettle.

The cake of sublimate can only be got out of the bolthead by cutting off first the neck, then the bottom, and afterwards carefully breaking away the glass from the cake of sublimate.

To avoid this continual breaking of the glass in the repeated sublimation of the same substance, chemists use a long oval bolthead, with the neck placed on the side. This philosophical subliming egg being charged and placed on one of its ends, both of which are made thin for the purpose, the sublimate rises and is condensed in the other end of the longest diameter; the egg is then turned and the sublimate driven by the heat to the other end, and this repeated as often as the operator pleases.

Geber, about 800, proposed to make the bolthead in two pieces, by dividing the globe in the middle; but his advice has not been followed. Sublimation, however, is sometimes performed in two crucibles placed mouth to mouth, and closely luted; the sublimate being collected in the upper inverted crucible, whose bottom is guarded from the radiant heat of the fire by being placed out of the furnace. This may be looked upon as an adoption of Geber's suggestion.

Sublimation is also sometimes performed in a common earthen pipkin, on the mouth of which a paper cornet or cap is tied.

When chemists formerly wanted to have the sublimed substance in a powdery form, or flowers as they are called, they used a series of earthen or glass blind heads, open at top, the first placed on a cut body, and the other on one another; the last, or topmost being covered with a close glass blind head: but Homberg, in 1700, recommended driving over the volatile matter from a low short-necked retort into a very large glass receiver, as some chemists do at present, half-filling the receiver with water.

COMMON DISTILLING APPARATUS.

This is of a more complex nature than any of the preceding apparatus, especially when aeriform products are to be collected, but for the present, only the common apparatus is considered.

The common copper still has been already described in treating of furnaces, in page 71, which serves for distilling the essential oils of plants, and the spirit of fermented vegetable juices and decoctions. An immense variety of these stills have been contrived for the latter, as will be shown hereafter, as they are solely destined for the manufacture of that single article.

Retorts.

Retorts are the most employed of any kind of distilling vessels in the practice of modern chemistry, having in England almost superseded the use of all others. Formerly bodies, or matrasses with glass heads, were chosen for many operations, but large retorts, with proportionate receivers, are now preferred, except in particular cases.

The common form of retorts is not faulty, provided two kinds of them be had; the one short and thick, with short wide necks, resembling a body bent in the middle; and the other taller, with long, narrow necks, resembling a matrass with its neck bent down. The particular use of each of these kinds will be pointed out, in treating of the several operations to which they are intended to be subservient.

But it will be found very advantageous to have a stock of both sorts ready for all occasions; and to be prepared to render the necks shorter, and enlarge their orifices, according to the designed use.

It is usual to have this done at the glass-house before the retorts are sent from thence; but every good operator should perform it himself, in the manner suitable to the use the retort is to be applied to; for, on the adapting properly the size and form of the retort to the nature of the operation, the success, in many cases, depends in a greater degree than can be imagined by those who have not occasion to make accurate experiments of this kind.

For dephlegmating oil of vitriol, distilling ether, and many other such occasions, the retorts may be made of the substance of which the pots, &c. commonly called stone-ware, are formed. These stone retorts being much stronger in their texture, and not near so liable to be cracked with heat, will endure much longer than glass, and are much less dangerous in placing into the furnace, or taking out, if there be occasion, when containing acid spirits or other corrosive fluids. They may be obtained at the stone manufactories, at an expense but little exceeding that of glass; and they afford by their durability, a great saving compared to glass, where much business is done.

For ordinary purposes, retorts of green glass are used, either placed in baths, or coated and used in a naked fire; but for some purposes flint glass retorts are obliged to be used.

The sizes of glass retorts are prodigiously varied, more so than that of any other vessels: large green glass retorts are used that hold several gallons; while, for experiments, others are blown that really hold only a cubic inch of any liquid. It must be observed, that the denomination of a green glass retort, and its real content, are widely different; as the manufacturers use, it would appear, the St. Denis pint, from whence the manufactory was probably introduced, as their initial measure, which is equal to four English wine pints, and only reckon half its real content.

Some glass retorts have, in their arch, or helm as it is called, an opening to admit the addition of fresh matter during the operation; these are called stoppered retorts, or tubulated.

Retorts are also made of crucible ware, when it is necessary to expose the substance to be distilled to a very intense fire.

These retorts are so porous that they allow both air and water to pass through them when intensely heated; and, therefore, they must be coated. The English retorts of this kind are of the ordinary shape, but the Waldenburg, or German retorts, so highly praised, even by that ancient author, Basil Valentine, and still esteemed by the German chemists, resemble a bolt-head, with its neck so slightly bent in the middle that the retort is obliged to be set sloping in the furnace, to allow the liquid condensed in the neck to run into the receiver.

Earthen retorts are also sometimes made with an opening in their arch, or, as it is called by the manufacturers, stoppered.

Boerhaave, in his reverberatory furnace, used cylindrical retorts laid on their side, as already described, when that furnace was mentioned in page 85.

This cylindrical form of the retort has been recently much used for distilling wood, coals, bones, and other vegetable, animal, or bituminous substances. The cylinder being made of cast iron, open at one, or more commonly both ends, but stopped, while in use, with a flat plate of the same metal. That in the front of the furnace has a short neck, to which the pipe, conducting the vapours that rise from the substance, is connected; the hind plate, when there is one, takes off for the purpose of charging and emptying the retort.

In the distillation of any of these substances, the manufacturer should remember, that if the retort be allowed to cool every day, it will be soon destroyed by the action of the air; but if it be constantly kept at work; by discharging and recharging it without cooling, the vessels will wear for several years.

When it is necessary to cool the residuum gradually, as in distilling wood for charcoal, intended as an ingredient in making gunpowder, the cast iron cylinder is, in fact, only the coating of the real retort, which is made of sheet iron, and slips into the other, so that when the distillation is finished, it is drawn out, and a fresh retort, ready charged, is put in its place.

Alembics, or Bodies and Heads.

Of all the vessels destined to this use the alembic is the most ancient. It differs from the retort in being generally composed of two pieces, the cucurbit, or body, into which the materials to be distilled are introduced, and the capital, or head, in which the vapours are condensed, and which fits closely on the top of the body, which is cut so as just to rise above the channel of the head. The capital, or head, has its external circumference, or base, depressed lower than its neck; so that the vapours which rise, and are condensed against its sides, by the contact of the surrounding air, runs down into the circular channel formed by its depressed part, from whence they are

conveyed by the beak, or nose, on the side of the head or capital, into the receiving apparatus.

The capital is sometimes stoppered, or pierced, that is to say, it has a small opening at the top, furnished with a ground stopper. This contrivance is convenient for introducing, from time to time, a fresh supply of materials intended to be distilled, without deranging the apparatus. The capital, or head, is sometimes made air tight to the body by grinding, or even made of one piece with it; but this method is expensive, and little, if at all, superior to closing the joint by lute.

Some authors have directed the neck of the head to be placed within the mouth of the body; but this would require them to be always ground together; when the neck is blown of a proper roundness, it fits the outside of the body so as to require scarcely any lute.

The alembic has this advantage over the common retort, that the residues of distillation may be easily cleared out of the body, which is not the case with the retort. It is likewise capable, when skilfully managed, of distilling a much larger quantity of liquid in a given time, than a retort of equal capacity. Besides this, the alembic may be used for causing the vapour of bodies to act upon substances in a more convenient manner than can be done by means of the retort and receiver.

Glass bodies are usually made from one pint to two gallons capacity; and are occasionally pierced, and even stoppered on the side, at about half their height. They are sometimes made of earthenware, or pewter, and the head only of glass; or of iron, with a stoneware head. A silver body, with a glass head, is necessary for the preparation of the pure fixed alkalies, and with a silver head for preparing fluoric acid.

Platinum boltheads, with heads of the same metal, are used in the concentration of oil of vitriol.

These alembics are very expensive in the first instance; that of Mr. Parke's cost three hundred pounds; but the frequent accidents which happen, in concentrating the acid in glass, counterbalance the expense.

It must be observed, that at the temperature in which this concentration is effected, lead unites with platinum, and they melt together. So that it has happened, that some small grains of lead having fallen into a platinum alembic, have made holes through it: the utmost care should, therefore, be taken, to avoid this mischance. But should it happen, the damage may be repaired by soldering in small plates of platinum, by means of pure gold.

Glass matrasses, with glass heads, are also used as alembics; these heads are generally of white glass and stoppered.

A series of heads, the lower being all open at the top, are sometimes placed one on another, by which the operator endeavours to procure the distilled liquor of different strengths, according to the height the vapours are made to rise; this apparatus is called a *hydra*, from its numerous heads.

Other chemists have endeavoured to send over only the most volatile parts into the receiver, and to let the other return into the body; for this purpose, some, as the old chemists, used a long winding neck to the body, on which the head was fitted, and this vessel they called, in the mysterious cant in which the chemists of all ages, even to the present day, take delight, a *serpent*: others,

in later times, have prolonged the top of a blind head to a great length, and brought it down again, in a similar winding course, to a level with the other part of the head, as Barchusen, as may be seen in the view given of his laboratory, in plate 11.

All these glass vessels which are exposed to heat, require some management and care to prevent them from breaking. If any solid substance be put into a retort, or body, which adheres to the bottom of it, when over a lamp, it is almost sure to break.

If a glass retort be laid down, while hot, upon a substance capable of conducting away the heat from it rather quickly, there is almost a certainty that it will break; but it may be laid down upon a piece of woollen cloth, a roundel of straw, bound with list, or on dry glass, or even very dry sand, with safety.

Receiving Vessels.

Receivers, properly so called, are large glass globes, which should be also always had with short and wide necks, so that the hand may be introduced with ease to extract any solid matter, or to clean them. They should be much larger, for most purposes, than what are generally used. A greater quantity of condensing surface renders the operation both more profitable and safe: it prevents the forcing of the lute and the escape of the vapour, as well as the hazard of bursting the vessels, on raising the fire too high, if the luted juncture should hold good against the force of the expanded vapour; or the necks of the retort, or adapter, and receiver, should fit so exactly as to admit no passage for it.

As the mouths of receivers, properly so called, whatever may be their size, should always be of nearly the same width, and the retorts, and beaks of the heads, to which they are to be adapted, are of many various diameters, the chemist must have a sufficient number of adapters. These adapters are pipes of white glass, about two feet long, one end of which is fitted to embrace the neck of the retort, and the other to fit into the neck of the receivers.

Besides their use in adapting the beak of the retort, or of the alembic, to the neck of the receiver, adapters have a farther use in removing the receiver farther from the furnace, and thus keeping it cooler.

When the vapours require a considerable degree of heat to raise them, and come over very hot, if the drops fall on a cold part of the receiver, they are apt to crack it; in this case, if the neck of the retort is short, another kind of adapter must be used to lengthen it, so as to reach the very centre of the receiver, that the hot drops may fall into the liquid that has previously come over, or into some liquid placed there for that purpose: these adapters are sometimes of stoneware, or even of iron.

Receivers are generally made of green glass, but when white glass adapters are used, stoneware jugs of sufficient size may be used for receivers, as the progress of the distillation may

be judged, by the temperature of the adapter, and the appearance of the vapours in it.

As the substances disengaged by heat are sometimes not condensible, even by putting water or other liquids into the receiver, a passage must be left for them. Some, before luting, put a piece of stick between the joint of the retort, or adapter, and the receiver, and take it out occasionally; but the more ordinary method is for the chemist himself to make an opening in the globular part of the receiver, taking care in placing it that this hole is uppermost. For common purposes the hole is stopped with a bit of stick, and hindered from falling in by a collar, or with a piece of soft wax. The flint-glass receivers, used by lecturers and amateurs, have a hole surrounded by a collar, to which is ground a glass stopper, by the manufacturer.

If it is supposed that the vapour is condensible, although with difficulty, a long and wide barometer cane is luted into this hole, so that the atmosphere acts like a stopper on the vapour: steam and air, not easily mixing together, but remaining perfectly distinct in pipes; and even for a long time in the open air, as may be seen daily in wash-houses and brew-houses.

For the purpose of taking away a part of the liquid product, during the progress of the operation, without the necessity of unluting the joints, some receivers have a short pipe, called a quill, on their sides; so that when they are fitted at a proper angle to the retort, the quill may be in the most depending part of the receiver, hence the liquid that comes over, flows thus into a bottle placed to receive it, and which may be removed occasionally, and the bottle have its place supplied by another.

Instead of allowing the uncondensible produce to pass out, an attempt is sometimes made to retain it in the vessels for some time, to allow it to deposite all the condensible parts, by increasing the size of the receiving apparatus beyond that of a single receiver; so that the additional pressure of the newly-produced aeriform fluid above that of the atmosphere being rendered less in proportion to the capacity of the vessel, may not occasion an explosion of the vessel. For this purpose, receivers are made with a second neck opposite to the ordinary opening; this neck is conical, to fit into the mouth of the next receiver, and thus a long file of these vessels is formed.

Various combinations of the above-mentioned kinds of receivers are used to suit the various purposes of the chemists.

Instead of these wide short-necked receivers, glass alembics have very commonly a matrass luted to the beak of the head to serve as a receiver.

Feeding Apparatus.

There is often occasion to add to the matter in the retort, or other distillatory vessel, some substance to produce certain effects; without admitting air or letting the vapours escape through the hole by which they are introduced, and several apparatus have been devised for this purpose.

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Fig. 70.

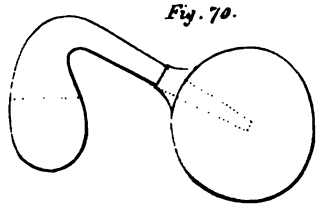


Fig. 71.

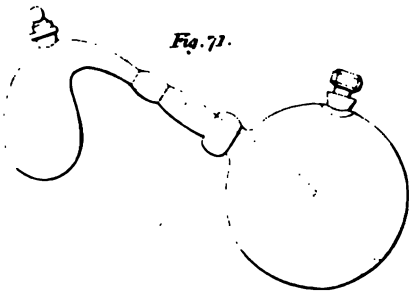


Fig. 72.

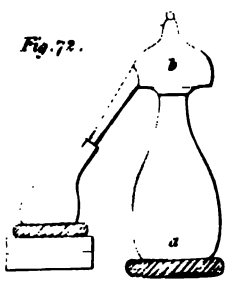
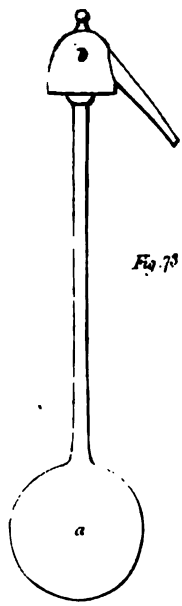


Fig. 73.



The most simple is the glass funnel and rod; the funnel has a very short pipe just sufficient to fix it in the hole in the arch of the retort, or the top of the head, and is stopped by a solid glass cane, which is ground to fit the throat; the liquid, for substances of that consistence can alone be used in this manner, is poured into the funnel, and by loosening the cane, it is allowed to drop or enter the vessel in a gentle stream, as may be judged proper, or its entrance may be instantly stopped.

Another apparatus of this kind, not more efficacious and liable to accidents, but certainly more tricksome, and therefore better adapted for a popular lecturer, is the hydrostatic funnel, in which the liquid itself serves as the stopper. A very long glass cane is luted into the hole in the arch of the retort, rising up perpendicularly, then bent so as to reach down within an inch or two of the hole, and again bent upwards to reach three or four inches above the first bend; this upper extremity of the cane is either widened or has a very small funnel placed in it. The liquid which is to be added to the substance in the retort, is poured into the cane until it stands in the second uprising part on a level with the bend, between the first upright uprising part and that which descends. This portion of liquid serves as a stopper: whatever is to be added is then poured at the proper time, into the upper extremity of the glass cane. Should, however, at any time, the vapour in the vessel be suddenly condensed by absorption or otherwise, the whole of the liquid in the cane is suddenly jerked, by the pressure of the atmosphere, into the bowl of the retort, and breaks it. On the contrary, if the vapours or gases in the distilling apparatus increase, the liquid is pushed up the cane, and is thrown out at the top.

To a still more complicated apparatus of this kind the name of Acid Holder is given, which is a flint glass bottle, open at both ends, furnished with a glass stopper at the upper end, and a short pipe with a glass cock at the lower end. Its use is to convey an acid, or any other liquid into a retort or apparatus, to which it has been previously adapted, without admitting the external air into the vessel, or suffering the gas within to escape out of the vessel.

This contrivance is very useful for preventing vapours or gas from escaping into the laboratory during the process; a circumstance of considerable importance when the gas or vapour has an unpleasant smell, or is of an unwholesome nature.

The cock being shut, the acid holder is filled with the liquid, and is then fixed into the opening of the retort, to which it is accurately adapted by grinding.

If it be found necessary to renew the liquid without disturbing the apparatus, this may be done as follows. The cock being shut, the stopper at the top of the acid holder is removed, and fresh liquid poured in through the mouth; this may be repeated as often as is necessary.

The size of the acid holder is usually from a quarter of a pint to a half; they are seldom used but in experiments to ascertain points of theory, or in giving lectures to the higher classes of society, when the vapours or gases have a disagreeable smell, or effect upon the lungs; as the admission of these elastic fluids into the lecture room might cause an audience of this kind to desert the lecturer.

The following figures represent some of the various articles of apparatus lately mentioned.

Fig. 70, a retort, with a receiver, not luted.

Fig. 71, a stoppered retort, with an adapter, and pierced receiver.

Fig. 72, a glass alembic, composed of a body, *a*, and its head, *b*, which is stoppered: to these distillatory vessels is attached a bolthead for a receiver.

Fig. 73, a glass alembic, composed of a matrass, *a*, to which is fitted a glass head, *b*.

Fig. 74, a pierced retort, fitted with a funnel and rod.
Fig. 75, a pierced retort, fitted with a hydrostatic funnel.
Fig. 76, a pierced retort, fitted with a stoppered acid holder.

APPARATUS FOR PNEUMATIC DISTILLATION.

The next class of apparatus is destined not only for collecting the solid and liquid substances volatilized from bodies by heat, or obtainable from them by mixture, but also the aeriform substances, usually called gases or airs.

The method of collecting these elastic fluids or gases, although simple, is not however obvious at first. They differ so little from the atmospheric air in density, that they are not sufficiently ponderous to be detained in open vessels; besides, they all mix with one another in a very short time; and many of them act upon bladders in which they were at first collected. Their remarkable lightness, however, affords a method of confining them by means of denser liquids, for which purpose water and quicksilver are used.

The first requisite, therefore, is the water-trough, or hydropneumatic apparatus, as it is called by those who delight in grandiloquence; these troughs are made of various sizes.

Large troughs are made of wood, and lined with lead, about four feet long, three wide, and two deep; having a wooden shelf fixed at one end of the trough, about three inches under the surface, and reaching about one-third of its length. This shelf is perforated with holes, for the convenience of pouring the gases from one jar to another, by means of a very shallow and broad funnel of light wood stuck in the funnel.

Small water-troughs are, for the sake of lightness, usually made of thin iron plate, and japanned both within and without. They have two handles, by which, if not too large, they may be removed from one place to another, even when full of water, and a cock near the bottom to let out the water.

Fig. 77, represents the small japanned troughs usually sold in London, and being about eighteen inches long, nine broad, and fourteen deep. The shelf is of the same material, and about three inches and a half below the top. This shelf is moveable, as it runs in a groove, and has, near its outer edge, two or more holes, *a*, to which are soldered, underneath japanned funnels, to secure and convey the gases to the vessels in which they are to be collected. They have also two other holes, *b*, in the hinder part of the shelf, into which are occasionally placed bottle-holders, *c*, to support narrow mouth bottles, which would not otherwise stand firm.

When this trough is to be used, it is to be filled with water, so that it may rise about an inch over the shelf. Now if a bottle, *d*, or any other vessel, is plunged into the water with its mouth uppermost, it will fill with water, and, on being turned in the water, so as to have the mouth downwards, and slid upon the shelf, it will remain full of water, for the water is supported in it by

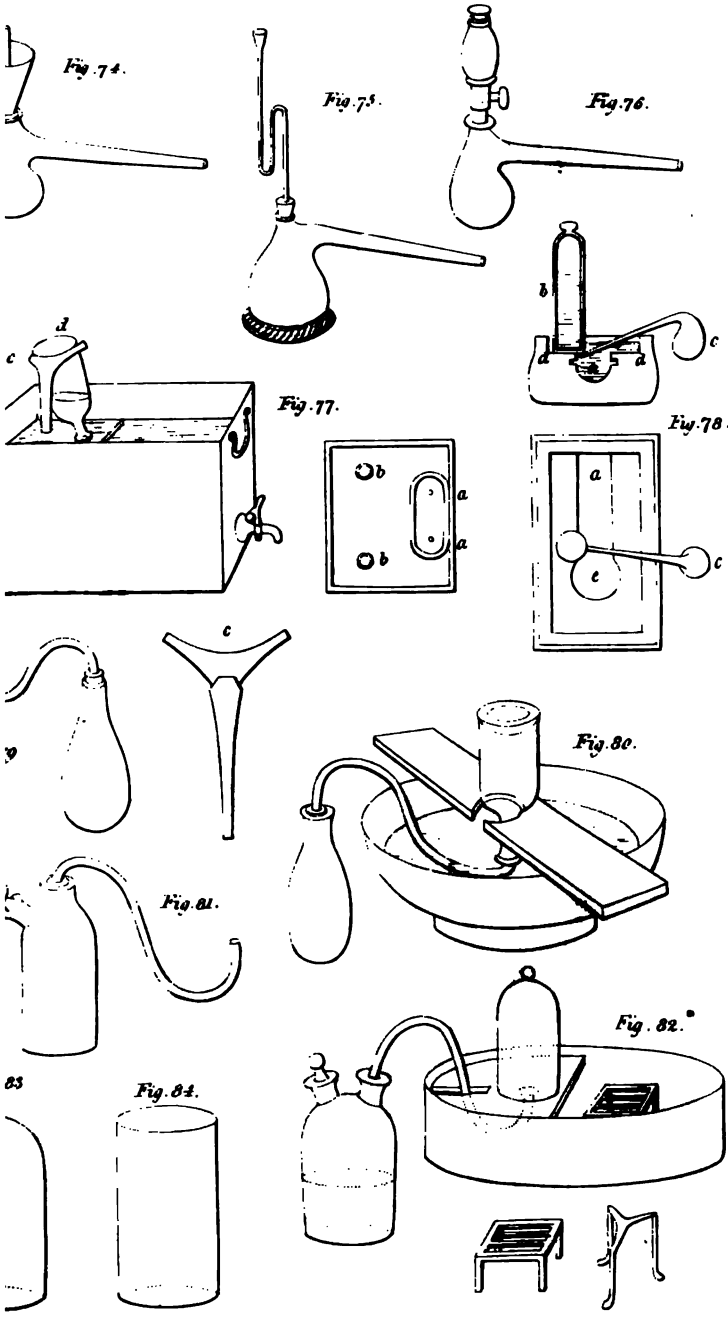


Fig. 74.
Fig. 75.
Fig. 76.
Fig. 77.
Fig. 78.
Fig. 80.
Fig. 81.
Fig. 82.
Fig. 84.
a
b
c
d

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pressure of the atmosphere in the same manner as the quicksilver in the meter.

another empty bottle, as it is usually called, though really full of air, be into the trough, mouth downwards, scarcely any water will enter, and if bottle be brought under the edge of the shelf, and then slowly turned up, air escapes in bubbles, and, if the operation is properly conducted, will through one of the funnels and holes, *a*, into the bottle standing on the f, and thus gradually expel the water and take its place.

is in this manner that chemists transfer any kind of gas or air out of one el into another, by causing it to ascend by an inverted pouring, in which lighter fluid is made to ascend from the lower vessel under the shelf, to the er vessel standing on it, by the action of the weightier fluid.

Many gases are so quickly absorbed by water that it is necessary to receive them in vessels placed in a trough filled with cksilver. These quicksilver troughs, or mercurial pneumatic apparatus, are made of marble, or cut out of a solid block mahogany. On account of the weight and expense of this uid metal the trough is made smaller, and the cavity for the mersion of the vessel is no larger than is necessary; the broad llow part of the trough supplies the place of a shelf, on ich the jars may stand, and there is put occasionally an acl shelf, at one end of the deep cavity.

ig. 78, represents a quicksilver trough cut out of a solid block of stone lose wood. The deep space, *a*, admits the jar, *b*, to be immersed, and n full it is raised and placed, bottom upwards, upon one of the shallow ks. *C*, is a retort, from which gas being extricated, rises up in bubbles and laces the quicksilver. *D*, are two grooves for a shelf, when required, ch must be put in at the wider part, *e*. The best quicksilver troughs are le out of a much deeper block, and have a deep cylindrical hole at one end, hich a small cylindrical jar may be sunk, so that the surface of the quicksr in the jar and the trough may be upon a level.

he glass jars used with this trough must be much smaller than those used he water-trough; and they ought to be stout, as they are liable to be overed, in consequence of their buoyancy, in so heavy a liquid as quicksilver, must generally be supported by bottle-holders, fixed to the side of the gh.

When only the aeriform product is to be collected, small retts, with long beaks, may be used to prepare and transmit it the vessels in the trough, as represented in fig. 78, or small theads, with a bent hollow glass cone, passed through a k, and luted, fig. 79, may be used: if this apparatus is too ple and cheap to please the chemist, gas-bottles, either plain, 80, or stoppered, figs. 81, 82, may be purchased with bent es ground into them: it is generally necessary to cut off part the tubes, with which they are usually too plentifully furhed, before they can be conveniently used.

To receive the gases, or airs, as they pass into the trough, most simple apparatus are glass bottles. These may be filled after another, and, being stopped with corks, or ground ppers, while they are in an inverted position, with their uths under water, may be placed, mouth downwards, in a ge trough, or cistern of water, until they are wanted.

Bell-glasses, fig. 83, or cylindrical air-jars, fig. 84, are generally used when the gas is to be used immediately.

When all the products are to be collected, whether dense or gaseous, a more complicated apparatus is necessary; and a number of them have been contrived by different chemists, of which only those useful in practical chemistry will be noticed.

The apparatus of Mr. Pepys, and Burkett, however ingenious, are passed by on account of their glass valves; and that of Girard, because it does not admit of sufficient pressure being given.

Hassenfratz's Compound Distillatory Apparatus.

The distillatory apparatus pointed out by M. Hassenfratz to M. Lavoisier, generally consists of a retort, *a*, a pierced receiver, *b*, and a series of bottles, *c*, connected with each other, and with the trough, by bent hollow glass canes, *d:* an adapter is also generally used.

The receiver, *b*, fig. 85, is designed to collect any condensible part of the product. In the three bottles water is placed to nearly one-half their height, and the canes passing from the one into the other, beyond the second bottle, *b*, dips into the water of the bottle into which it is inserted, as is represented in the plate.

The gaseous product is thus transmitted through the water, by which, as well as by the pressure which is necessarily exerted by the short column of water in each tube, its absorption is promoted; and if any portion is incapable of being absorbed by the water, it passes off by the bent cane at the end, and may be collected in a bottle or jar, inverted in a trough of water.

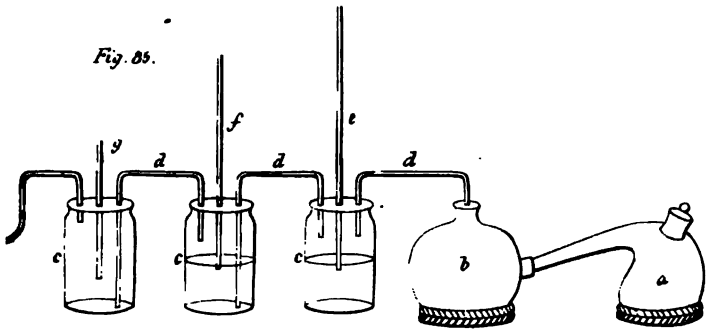
Each of the bottles, except the receiver, has a straight cane, *e*, *f*, *g*, which rises to the height of about ten, thirteen, and sixteen inches above its insertion into the bottle, and passes so far within it, as to dip into the water nearly half an inch. These canes are termed the safety-pipes, and the use of them is to guard against that reflux of fluid which might happen from a partial vacuum arising from condensation in any of the bottles.

It is evident that, in the course of operations with this apparatus, the liquor of the bottles must rise in these tubes in proportion to the pressure sustained by the gas or air contained in the bottle, and this pressure is determined by the height and gravity of the column of fluid contained in all the following bottles. Now, supposing that each bottle contains three inches of water, and that there is the same depth in the cistern of the connected apparatus above the orifice of the tube, *d*, and allowing the gravity of the fluids to be only equal to that of water, it follows that the air in the first bottle must sustain a pressure equal to twelve inches of water; the water must, therefore, rise twelve inches in the cane, *g*, connected with the first bottle, nine inches in the cane of the second, *f*, and six inches in *e*, that belongs to the last; wherefore these tubes must be made somewhat more than twelve, nine, six, and three inches long, respectively, as an allowance must be made for oscillatory motions, which often take place in the pipes.

It is sometimes necessary to introduce a similar tube into the receiver itself, and as the tube is not immersed in a liquid at its lower extremity, until some has collected in the progress of the distillation, its upper end must be shut at first with a little lute, so as to be opened according to necessity, or as soon as there is sufficient liquid in the receiver to secure its lower end.

At the commencement of the distillation, the joinings of the canes with the bottles being well secured, the whole is air-tight; and, by the gas produced, the atmospheric air contained in the upper part of the bottles is, in a great measure, expelled through the tubes. If, therefore, in any stage of the distil-

Fig. 85.



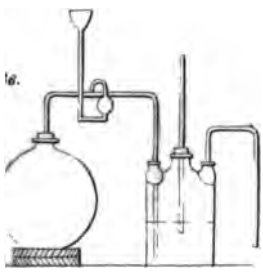
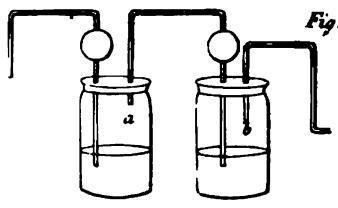


Fig. 87.



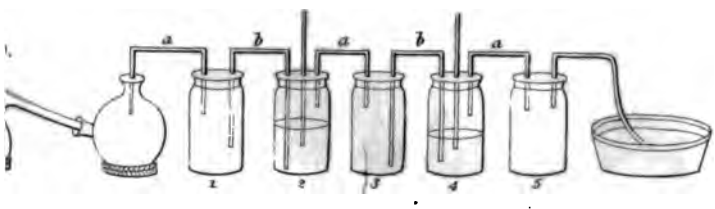
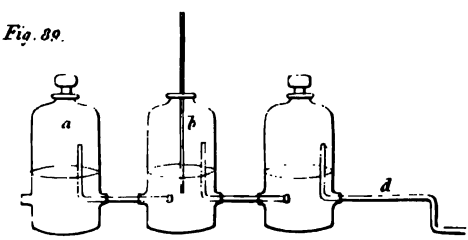
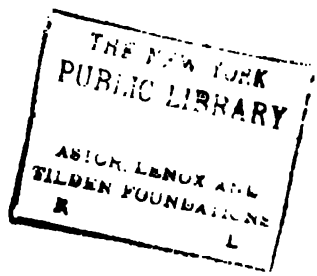


Fig. 89.

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he production of gas should diminish, then, on the quantity contained ottles being absorbed by the liquor, a partial vacuum will be formed; he end of the process, when the retort cools, this must always happen. nsequence of this will be, that the water in the trough being more on by the atmospheric air without, than by the gas within, would pass rds from one bottle to another, by rising through the tubes; and thus le of it would be mingled together in the receiver, which would often he object of the distillation. The safety pipes effectually prevent this, any such partial vacuum happens, the atmospheric air is forced into them through the small quantity of fluid in which they are immersed, ng into the bottles, preserves the equilibrium.

defect in this apparatus is, that the advantage of the im- n of the cane which passes from the receiver into the in the first bottle is lost; for, as the receiver is almost designed to collect the condensible product, and ought, ore, to be without water, it can have no safety tube; and if the tube issuing from it dip into the liquid in the se- whenever any condensation happened, from the gas ceas- be produced, the liquor would pass backwards into it. pparatus, therefore, is represented as it ought to be, with nt tube from the receiver only reaching near the surface liquid in the bottle, *b*, while in the others it is im- l.

he liquid, however, in this first bottle, is in the best si- for being impregnated with the gas, and, therefore, for g the most concentrated product, it is of some import- aid this as much as possible, and to obtain the advan- the gas being forced to pass through it, by the tube pass- o it being immersed.

Welter's Safety Pipe.

ontrivance that has been used for this purpose by experimental che- Welter's safety pipe, or bent tube, with an additional curvature, and a l ball, as intermediate between the globular receiver and the first bottle, necting them.

safety pipe, which is represented in fig. 86, is put a small quantity of as to rise, when the pressure without and within is equal, about half the ball. If the elasticity is increased in the internal part of the ap- during the distillation, by the production of gas, the water is pressed to the funnel at the top; if there is a condensation, it is forced by the eric pressure into the ball; but whenever it has passed the curvature the ball, it is obvious, that a portion of air must rise through it, and into the globe, or bottle to the tube of which this bent tube is

safety-pipe, however, though it answers the purpose ef- y, is inconvenient; from its form, it is very liable to be ; and, what is its principal defect, we can employ no pressure in the apparatus with it, without making it of length as to be unwieldy, and still more liable to be , since the bend must be as long as the cane in the first or even longer.

Murray's balled Pipes.

The method employed by Dr. Murray, to obviate this inconvenience, is more simple.

It consists in having the usual bent glass canes constructed with a ball in that leg of it which is inserted in the bottle containing the liquid into which it is to dip, as represented in fig. 87. By properly proportioning the depth to which the tube is immersed in the liquid in *b*, to the size of the ball, it is obvious, that when from any condensation in *a*, the liquor in *b*, rises and fills the ball, the extremity of the tube will be no longer immersed; a portion of the gas will therefore rise in it through the water, and preserve the equilibrium, so that if the tube be not too deeply immersed, no part of the liquid in *b*, can ever pass into *a*.

The use of balled pipes of this kind, supersedes entirely the use of safety-pipes, through the whole apparatus; for, if the depth to which their lower ends are sunk in the liquid in the bottle be duly proportioned to the size of the ball, the reflux of the liquid will be totally prevented, while a pressure of any extent may be obtained by a pipe issuing from the last bottle, being sunk in the water, or quicksilver of the trough, to any desired depth.

This apparatus is certainly the best hitherto proposed, nor does it seem probable that any great improvement can be made in it.

Coxe's Apparatus.

Dr. John Redman Coxe, Professor of Chemistry in Philadelphia, communicated to Dr. Thomas Thomson, an apparatus nearly of the same nature as the last, which was published in the Annals of Philosophy, for 1813, and is of easier execution than the apparatus of Dr. Murray, as it requires no other but the common barometer canes, although in other respects inferior.

To the pierced receiver of the usual distillatory apparatus is annexed a series of an unequal number of bottles, the first, third, and fifth of which are empty, the second and fourth half filled with water or any other appropriate liquid, as represented in fig. 88. Particular attention is to be paid to the arrangement of the glass canes; those from the receiver to the first bottle, the second bottle to the third; and the fourth to the fifth, *a*, have both their legs very short, so as to descend not more than half an inch below the opening in the retort, and the mouths of the bottles; on the contrary, those from the first bottle to the second, and the third to the fourth, *b*, have their legs sufficiently long to reach to the bottom of the bottles; and that from the fifth to the trough only descends a little below the mouth of the bottle.

Straight glass hollow canes, *c*, of different lengths, on the principles already pointed out, are inserted into the mouth of the bottles which have the water or other liquid put in them, and descend about half an inch below its surface.

Now if any condensation or absorption takes place, the liquid in the next succeeding filled bottle, or in the trough, will be drawn up the canes, and pass, at least in part, into the bottle left empty for that purpose; but it cannot go farther backward, because, as soon as the bottom of the safety pipes, *c*, are

ift bare, the atmospheric air will enter by them, and thus pre-ent the liquid in the following bottles, or the trough, from eing drawn over. And although the liquid in the second bot-le may still continue to rise and pass into the first, by the pres-ure of the atmosphere through the safety-pipe, yet, as the cane onnecting the receiver and the first bottle, merely enters the rst bottle, and does not descend to any depth, the liquid can-ot pass by it into the receiver. And the case is the same with he liquid in the trough.

When this absorption or condensation has taken place, and he production of vapour and gas continues, as soon as they re sufficient to support a column of liquid equal to the height f the legs of the longer canes, the water or other liquid hich has come over into the bottles that had no water or other quid placed in them at first, will be forced again into its former ituation.

If a stoppered retort or other distillatory vessel is used, and the operator hances to observe the absorption or condensation, the atmospheric air may e readmitted into the apparatus still more readily by opening it.

There is no absolute occasion for any safety-pipes in this ap-aratus any more than in Murray's, provided the operator is areful that the last empty bottle shall be of sufficient capacity o hold the liquid that may, on occasion of any absorption, flow ack into it, until the end of the pipe, which passes into the rough, be uncovered by the sinking of the liquid in the rough.

De Butt's Apparatus.

A very convenient distillatory apparatus has been invented y Dr. De Butt, of Baltimore. It consists of two or more bot-les, each of which have two openings made in them, opposite o one another, and near the bottom.

The first bottle, *a*, fig. 89, is connected with the distilling apparatus by means of a quilled receiver, or a hollow glass cane luted into the smaller neck of a double-necked receiver; one of the side holes is stopped. These are con-nected with the next bottle, *b*, by a tube straight without, but which has such curvature within the bottle, *a*, as to rise above the water employed to con-dense the gas, the surface of which is represented by the dotted line. The succeeding bottles are connected in a similar manner. And the last bottle has a pipe, *d*, that passes into the trough.

It is obvious that the gas passes forward through the bent tube, and is trans-mitted through the water in the next bottle. The tubes may be fitted by grind-ing, but it is difficult to have this done with perfect closeness; they therefore may be inserted by corks waxed; and as these are not exposed directly to the gas, but are under the liquid, they will, in general, be little acted on. Safety pipes are adapted in a similar manner; and as it is inconvenient to detach the bottles, the liquor, when the distillation is completed, may be drawn off by a syphon inserted into the mouth of the bottles, or by an opening in front at the bottom, fitted accurately with a stopper or waxed cork.

The peculiar advantage of the apparatus is, that all the join-ings, with the exception of the first, are under water, and the gas, therefore, cannot escape. Hence, in distillations, in which

the product is peculiarly offensive, as in that of chlorine, it affords the best security against any noxious effect.

Kerr's Gas Apparatus.

Persons who are but little or not at all acquainted with chemistry, are often deterred from attempting even any experiments that may occur to them, from an idea of the expense of the requisite apparatus, and the supposed want of room.

The mechanic sees immediately the economy that attends trying the effects of a new engine by means of a working model; the architect exhibits, in like manner, the effect of his design by a model far better than by a draught upon paper; and yet with but little outlay of money. The experiments of the chemist may also be made in a miniature at a trifling expense. Beecher, that indefatigable artist in this line, was the first that practised this microscopic chemistry, as it is sometimes called in contempt. Cronstedt succeeded; then Engestrom, Bergmann, Gahn, Wollaston, Marcet, and Berzelius.

The glass tubes, lately described by Mr. Kerr, are to be considered as a continuation of the same scale of experimenting as with the blow-pipe.

Fig. 90, represents Mr. Kerr's tubes. The simple tubes, *a*, are hollow glass canes from six inches to a foot in length, and from a quarter to nearly half an inch wide, and of course, will allow of operating upon a quarter of an ounce to three quarters of liquid. They are closed at one end, *b*, and bent a little below the middle, so that the two branches may diverge from each other nearly at a right angle; the closed branch being somewhat shorter than the open one. The bend of the tube should be widened on the hollow side, and that more towards the short than the open branch, as represented in the figure. The bulging part, *c*, of the convex side, does not correspond with *d*, that of the hollow or concave side, but is beneath the short branch.

From this form being given to the glass, the gas that is evolved from a liquid by its action on a solid may be collected with ease in the closed branch, in the following manner:—The tube is to be held so that the open end be the highest, and then the liquid is to be poured in until it rises a little above the bend. On turning up the closed end of the tube, so that it may be as high as the open end, the liquid will still remain in the closed end, being supported therein by the pressure of the atmosphere. The solid body being then put in at the open end, will fall down to the bulge in the bend on the convex side, and if any gas is evolved from the mutual action of these bodies, or by the action of heat, it will pass through the liquid, and be collected in the closed end of the tube, unmixed with common air. The quantity of gas evolved may be easily ascertained by pasting a piece of paper to the tube, and afterwards weighing the quantity of water required to fill that part of the tube.

The same tubes, or rather those of a larger size, may be used for discovering the quantity of gas absorbed by any liquid.

In these experiments of absorption the open end must be corked, that the absorption may be limited to the gas or air contained in the tube itself. The quantity absorbed may be discovered by pasting a paper mark at the places the gas stands at, both before and after the experiment, and weighing the quantity of water, the tube will hold between the two marks.

If the experiment require a considerable time to be perrmed, the bend of the tube may be passed through a slit in e shelf of the trough, *e*.

Mr. Kerr has since contrived another sort of these tubes, in der that the gas that is evolved at any period of an experient may be examined without giving any disturbance to the ogress of the experiment, by mixing any liquid with the marials in the tube, or even mixing the gas that is disengaged ith the air of the atmosphere.

These tubes differ, indeed, but little from those above described, except in much that they are open at both ends, and are bent in three places. The st part of the tube, *f*, being that by which the materials of the experiment e to be introduced, and which is bent horizontally at the bottom; and after little distance bent again upwards, as seen at *g*, the tube is then bent again wnwards, and this descending branch is open, but stopped at pleasure by a rk or glass stopper, *h*, ground to fit it. If cork is used, it will in general reire to be soaked in wax, and coated with that substance, in order that it may sist the action of acids.

The tube being closed, either with a stopper or cork, the liquid is poured to the first branch, *f*, until it has filled the whole of the second branch, *g*. he manner of doing this has been already described. The tube is placed so at its first bend, at the bottom of *f*, shall be its lowest point, and then the solid bstance is dropped into the liquid. When the action commences, the gas at is disengaged will rise into the ascending part, *g*, of the second branch, id will displace the liquid, forcing it to rise up in the first branch. But some f the liquid will still remain in the descending part, *h*, of the second branch; id this ought to be run back and mixed with the main body of liquid, which easily performed, by merely raising the stopper-end of the tube a little higher an the upper bend, between *g* and *h*. If the tubes are properly bent, so that ie angle formed by the branches, *g* and *h*, be greater than the angle formed y the branches, *f* and *g*, there will be no fear of spilling any liquid from the pen end of the tube, nor of introducing any atmospheric air to mix with the as that is collected.

For the purpose of transferring the gas that is formed into another tube, he lower end, *h*, of the descending part of the second branch, must be brought nder the surface of water or quicksilver in a trough; and the stopper or cork eing then taken out, as much gas as may be desired may be transferred.

For the convenience of making several experiments at one time, Mr. Kerr ses the small trough, *e*, ten inches long, seven inches deep and wide, with a shelf having four slits, for the purpose of holding the same number of tubes. This shelf, *i*, is placed on one of the sides of the trough, and rests on a bracket. Within the trough itself, and in the side next the just-mentioned shelf, is placed nother shelf, *k*, the length of the trough, that is to say, ten inches, about three nches and a half broad, and one inch or two below the surface of the water. This shelf has slits in it, which correspond to those of the shelf that hangs upon the edge of the trough. This construction of the trough was adopted that the liquid in the tube might be heated when necessary.

The first branch, *f*, is represented as having a globular enlargement, which is only necessary when this first branch would not otherwise be sufficiently large to hold the liquid forced out by the gas from the second branch, *g h*.

Ignited Adapters.

Volatile substances, when exposed to heat in the ordinary distilling apparatus, rise in vapour, and thus escape from the farther action of the heat: it is, however, frequently desirable to cause them to undergo its full operation. For this purpose, several contrivances have been adopted.

The first and oldest method is that of using a slender adapter, between the distilling vessel and the receiver, and making a fire round it, so as to ignite it thoroughly, and then beginning the distillation, causing the vapours to pass through it in that state. In order to prolong the action of the heat on the vapours, the adapter is sometimes filled with a substance to delay its passage, and thus cause its complete alteration by the heat.

For the purpose of heating the adapter, an extemporaneous furnace is generally made of bricks cut into two or three pieces; but Knight's furnace, fig. 640, has two holes, *g*, made on the opposite sides of the fire-room, to admit the introduction of an adapter of this kind.

When glass adapters are used, they grow so soft by the heat that the expansion of the air within them, which is hindered from escaping by the column of water or quicksilver, in the pneumatic trough over their mouth, that they blow up; hence they require to be wrapped round with thin sheet iron, to preserve their shape.

Earthenware adapters grow porous in the fire, and allow air and steam to pass through them.

Old gun barrels have been used occasionally for this purpose; but the metal is so easily acted upon by other substances that they are not fit for general use.

Lavoisier procured for this purpose a tube of brass turned and bored out of a solid mass; and others have used tubes, obtained in a similar manner, from a rod of copper.

When the vapours are not judged to be sufficiently altered by being made to pass through a single ignited adapter, two or more are used, and the vapours forced to pass from one to another.

BOTTLES AND FUNNELS.

Glass is now used for keeping the greatest part of chemical subjects and products, especially if liquid, even upon a very large scale: yet there are certain subjects that cannot be kept in it, as quicklime, for this attracting first moisture, and afterwards carbonic acid gas, from the atmosphere, swells so considerably as to break the bottle.

Vegetable powders are also considerably altered by the light that passes through glass, and ought, therefore, to be kept by apothecaries in boxes, instead of bottles.

It is common to keep solid articles, not liable to get moist, in drawers, both in laboratories and in druggists' shops; but prevents the arrangement of them being altered without

considerable trouble: wooden boxes or stone-ware jars, with covers of the same materials, are far preferable. All jars, of whatever size, which are used for keeping articles, ought to have covers of the same material, instead of the tedious way of tying paper or leather over them.

When bottles have been washed and drained, there still remains in them some traces of water, which, if the bottle is wanted for immediate use, it is frequently very troublesome to remove. Keeping them in a warm stove for hours, is less efficacious than blowing into them the blast of a pair of bellows; but dry, warm, coarse powder of the common stone, called trap, or whinstone, shaken in them, or some slips of dry blotting, or filtering paper, soon absorbs this moisture.

If the substance to be kept in the bottle is altered by the air, and it is desired to empty the bottle of it as far as possible, without the use of an air-pump; a piece of blotting, or filtering paper, or a small pellet of tow, may be soaked in spirit of wine, set on fire and put in the bottle. When it has burned a second or two, and while the flame is yet in its full strength, the bottle is to be quickly and carefully stopped.

Stoppered Bottles.

Glauber's invention of glass stoppers, fitted by grinding in the necks of bottles, is, in many cases, very useful; but cork confines volatile fluids far better than glass stoppers, excepting in the case when the cork is corrosible by the liquid.

When, however, a bottle is often opened, or long kept, the cork loses its elasticity, becomes loose, and requires to be changed.

There are some liquids, and even solids, that are almost incoercible by any kind of stopper; and others that cement glass stoppers so that they cannot be removed.

The mucilaginous oils can scarcely be kept in any vessel; Berzelius, in order to secure the oil in his travelling lamp from oozing out, formed the internal part of the neck into a female screw, into which the male screw of the stopper is received; and the joint between the rim of the lamp and the projecting top of the stopper, was secured by a collar of leather soaked in melted bees'-wax.

Iodine, although solid and even crystallized, gets through the joint of glass stoppers, cements them to the neck of the bottle, and will corrode a paper label on the outside. The case is the same with muriates of red oxide of iron, and several other articles. Chemists endeavour to guard against these untoward effects by greasing or waxing the stoppers, but this will not always succeed.

Double-rimmed Bottles.

The anatomists are much plagued by the volatility of spirit of wine, which escapes from their bottles, however carefully stopped and luted, and leaves their preparations dry. Glauber, in his fifth book on furnaces, 1648, but which in fact treats on the present subject, extended the method the chemists had long used for closing the tops of their tower furnaces, to bottles, and proposed the use of necks with double rims; the groove between which he filled with quicksilver, and then put on a cover. Several attempts have been made to improve this joint, the latest of which is to fill the groove with melted hog's lard: perhaps fusible metal might, by a little dexterity, be run into it. The different expansions, however, of the glass, and whatever substance is used, by the alternation of the seasons, will in all cases tend to open the joint, sufficiently to allow such a subtle liquid to escape. A method resembling that of Berzelius, in respect to oil, is the last proposal; namely, to press a sheet of Indian rubber on the rim of a common bottle by means of a screw, fitted to the neck by a collar.

Funnels.

Besides the common funnels, chemists have occasion for some others, such as the retort funnel, the pipe of which is bent sideways, and must be sufficiently long to reach to the bowl of the retort, so that the liquor may be poured in without soiling the neck.

The capillary funnel is used to convey liquids into the closed end of long, narrow, hollow, glass canes, without soiling the sides: as these funnels are very brittle, they are usually made, when wanted, by heating a piece of a hollow flint glass cane, near one end, and drawing it out suddenly.

Fig. 91, represents a method of filtering a larger quantity of liquid than the funnel will contain, without the necessity of filling it continually; as the liquid contained in the inverted bolthead is supported by the pressure of the atmosphere, and only runs down as the level of the liquid in the funnel getting below its mouth, allows a bubble of air to pass up into its bowl.

If two semicircular pieces of card-paper, with a notch in the middle for the neck of the bolt-head, be laid in the funnel, to rest just above the surface of the liquid, and a narrow mouth bottle used to receive the filtered liquid, the evaporation of the liquid, or the absorption of carbonic acid gas from the air, will be considerably prevented, and this apparatus is well fitted for filtering spiritous tinctures, or caustic alkaline leys.

Syphons, or Canes.

Syphons are vulgarly called cranes, an erroneous pronunciation of cane, the glass-house term for what are frequently called tubes, or rods: they are composed of two legs, the one longer than the other.

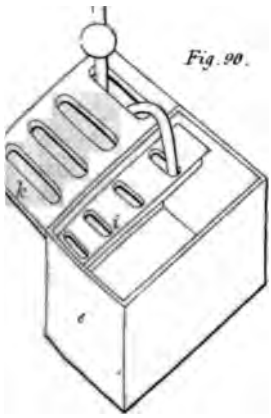


Fig. 90.
k
i
c

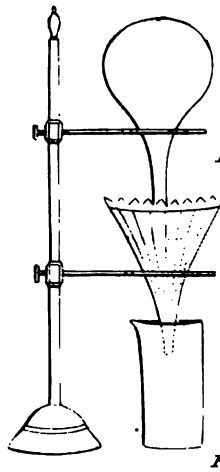


Fig. 91.

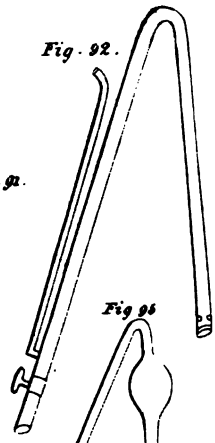


Fig. 92.

Fig 95

98.

Fig. 99.

Fig. 93.

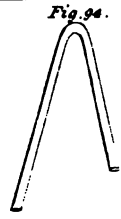


Fig. 94.

c

Fig. 96.

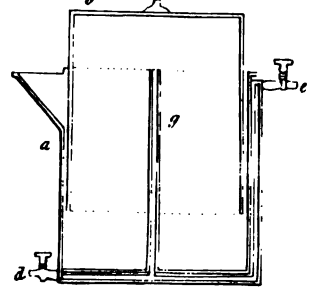
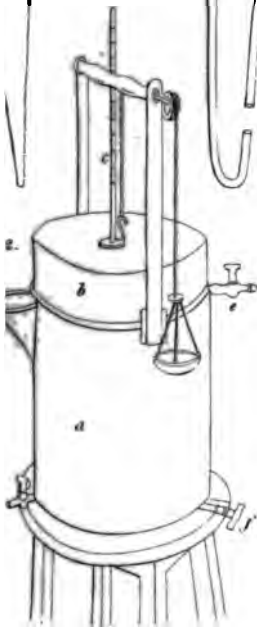


Fig. 102.
b
e
g
a
d


b
c
a
f

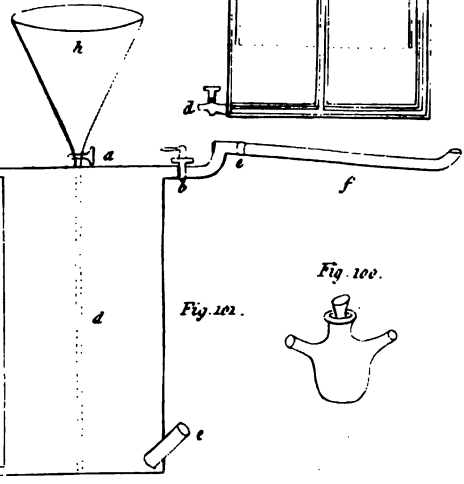

h
a
b
c
f
g
d
e

Fig. 100.

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R L

The common pewter cane, fig. 92, has a cock at the end of the long leg, and either a sucking pipe, or exhausting syringe, a little above the cock, to raise up the liquid in which the short leg is plunged, over the arch, and so to fill the long leg; after which the liquid will run over by the pressure of the atmosphere.

Several kinds of glass syphons are used in laboratories, either to decant liquids out of bottles, or other vessels, without the necessity of moving them; or to draw liquids off from sediments without disturbing them.

The double glass syphon, fig. 93, has a sucking-pipe, and is a miniature imitation of the common pewter cane; to avoid the danger of drawing any corrosive liquid into the mouth, by a careless use of the sucking-pipe, a bulb is sometimes blown near the top, so that the operator may see plainly when the liquid has reached the top of the sucking-pipe.

The simple cane, or syphon, fig. 94, is used in several different ways.

If the liquid to be decanted is not corrosive, and is contained in a wide-mouthed vessel, the syphon is inverted and filled with some of the liquid, and each end being then stopped with the fingers, the short end is plunged beneath the liquid, and the fingers withdrawn, immediately on which the liquid begins to run off.

If the liquid is corrosive, or contained in a narrow-mouth vessel, the syphon is passed through a notch in the cork, and through another notch there is also passed a short hollow glass cane, through which air is blown by the mouth, or a pair of bellows, joined to the short pipe by the neck of a bladder, or of a bottle of Indian rubber. This blowing of air into the vessel forces the liquid over the arch of the syphon, and causes it to run. The French use this method to decant oil of vitriol, or other acids, out of the carboys, or dames Jeannes, as they call them, in which they come from the manufacturers.

Bunten's Syphon.

The syphon of M. Bunten is shown in fig. 95, where *a*, *b*, is the long branch, with a bulb at *a*, and *c*, *d*, the short branch. This syphon requires neither blowing into the vessel, nor any suction. It is sufficient to fill the long branch, *a*, *b*, and the bulb, *a*, with the liquid, to stop the mouth of the long branch, and to plunge the short branch, *c*, *d*, into the liquid to be decanted. On removing the stopper, the bulb, *a*, in emptying itself, draws off the liquid in contact with the short branch; and though itself is partly empty, the running is unremitting.

Hempel's Syphon.

Another syphon by M. Hempel, a practical chemist at Berlin, is shown at fig. 96. It has the same advantages as that of M. Bunten, and consists of two syphons, one of which is inverted, joined by their short legs. A part of the liquid to be decanted is poured by the funnel, *a*, into the long leg of the inverted syphon, *b*, *c*, which is fitted into the short branch of the proper syphon, *d*, *e*. As soon as the flow commences through the syphon, *d*, *e*, the inverted syphon is withdrawn, and the flow continues.

For the purpose of drawing off the last portions of a liquid, a small glass syringe is very convenient.

Wine-Coopers' Cane.

Another sort of cane is used by the wine-coopers to withdraw the lower part of a liquid for examination.

Fig. 97, represents this cane, which is only a pewter or tin pipe, the upper end of which is made narrow that it may be stopped with the finger: the lower end is still smaller. To use it the upper end is stopped by the finger, and the cane is dipped into the liquid, which is prevented from entering by the resistance of the air; but when it has been dipped to a sufficient depth the finger is withdrawn for a short time, and then being replaced the cane is withdrawn. By again withdrawing the finger from the top, the liquid is allowed to run into a vessel for examination.

Separatories.

There are several kinds of vessels used for separating liquids of different specific gravities.

The common separating funnel, fig. 98, differs from the wine-coopers' cane, only in being enlarged in the middle for the purpose of holding a considerable quantity of liquid. The opening at the bottom of the pipe, which is very small, being closed by the finger or otherwise, the two liquids are poured into the funnel, and the top being stopped with a cork or stopper, they are left for some time to settle; when, the stopper being withdrawn from the top, the heaviest liquid is allowed to run out, and the lightest retained by closing the opening at top with the finger, as soon as the other has passed.

Some funnels of this kind have glass cocks in the pipe; but these are apt to get out of order, and their superior utility is by no means equal to their superior expensiveness.

The spout receiver, fig. 99, is a tall vessel, having a spout on the side, coming out about one-third the height of the vessel from the bottom, and whose bend at top does not rise above two-thirds the height of the vessel. On filling this receiver with two liquids of different specific gravities, and letting them settle, they may be poured out separately.

This vessel is frequently used as a receiver, when vegetables are distilled for their essential oil, as it, like the Italian receiver in fig. 7, allows the water to pass off into another vessel, and retains the oil equally well, whether it floats on water or sinks in it.

A receiver of this kind is sometimes used not only for separating liquids of different specific gravities, but also for sorting the powder of hard substances, which is not soluble in water or other appropriate liquid, into different finenesses. The powder and liquid being put into the receiver and stirred together, are allowed to deposite the grossest particles, and then the liquid, with the finest part yet suspended in it, is poured off into another vessel to settle. Sometimes a stream of water is allowed to run through this receiver while the powder is stirred, and thus the finest particles are carried off and allowed to settle in the vessel into which they are washed.

Another kind of separatory is a squat bottle, fig. 100, with a spout on each side, through which the liquids, when they have separated into layers, may be poured: but it does not seem to possess any advantage over the common apparatus.

GAS APPARATUS.

It has been already shown that the collection of the aeriform fluids, which are obtainable from substances by heat or admixture, require a peculiar apparatus, and that they are usually collected in bottles, or cylindrical air jars, standing in a trough of water or quicksilver.

These air jars are usually made tall and slender; but there is a great convenience to be provided also with some broad shallow jars, or the glasses used by the confectioners to cover their cates; their breadth causes gases to unite quicker together, and their shallowness is advantageous when the gases are to be transferred by a syphon into another jar, a bladder, or a gas measure.

Bladders are often used as gas holders; they are generally tied on to the brass ferrule of a cock, which furnishes the means of closing them. Silk bags, or those of gauze, varnished with a solution of Indian rubber in highly rectified mineral oil, are also used. These gas holders are frequently more convenient than vessels of a constant size.

Leeson's Gas Bottles.

Similar to these, except in elasticity, are the Indian rubber gas bottles of Mr. Leeson, described in the Quarterly Journal, as made from the bottles of Indian rubber. Those of a black hue generally become very thin and almost transparent by extension; the brown are much less yielding and cannot be extended to the same thinness as the black.

To prepare these bottles they should be boiled in water till they are completely softened, an operation which generally takes a quarter of an hour. When cold, the ferrule of a condensing syringe is firmly tied to the mouth, and air forced into the bottle. A blister first appears, and the whole bottle gradually enlarges; a half pound, or three-quarters of a pound, bottle will generally extend to fourteen or seventeen inches, and sometimes farther, provided it is chosen of a uniform substance, and free from defects.

Having been once gradually and cautiously expanded, these bottles may have a cock fitted to their mouth, and gas forced into them at any time; they are expanded to the same size as before without any danger; and their own elasticity will, on opening the cock, expel the gas, until they are reduced to their original size, or very near it.

These bottles may be used as an oxy-hydrogen blow-pipe, by having a blow-pipe jet screwed to the cock, and should an explosion take place, it would only occasion the loss of the bottle.

Watt's Air-holder.

When the quantity of gas prepared is considerable, it is necessary to be provided with larger vessels than any of those already mentioned to contain it. Such vessels are usually made of tin-plate japanned, or partly of tin-plate and partly of glass, and they are known by the names of gasometers, gas-holders, or air-holders.

Fig. 101, represents Mr. Watt's air-holder. It is made of tin-plate, well japanned, both withinside and without. It may be of any size; the vessel, of which this is a representation, held about two thousand cubic inches. It is a cylindrical vessel, close on all sides, and ought to be pretty strong to resist the pressure of the atmosphere, which tends to force out gas, or to force in air, according to the changes in its density which take place. It is furnished with three openings, *a*, *b*, *c*. The first, *a*, is at the top, the second, *b*, at the side, as high up as possible, the third, *c*, at the bottom. *A* and *b*, are each provided with a cock, the cock, *a*, is soldered into the pipe *d*, which goes to the very bottom of the vessel to which it is soldered, in order to increase the strength of the air-holder. This pipe, *d*, towards its bottom, is perforated with a number of holes. To the extremity of the cock, *b*, a piece of bent pipe, *e*, is ground so as to be air-tight, but to move freely round the extremity of *b*, which is turned up to receive it. And to the extremity of *e*, the long pipe, *f*, is likewise ground so as to be air-tight, yet capable of moving freely. These two tubes by their motion form a universal joint, so as to enable the operator to turn the extremity of the pipe, *f*, any way he thinks proper. The mouth, *c*, consists of a pipe about an inch in diameter, introduced into the vessel near the bottom, at an angle of about 45°. It is provided with a stopper, which screws into it, and shuts it close. *G*, is a hollow glass cane, fixed into the top and bottom of the air-holder, communicating with it, and furnished with a scale of equal parts, the use of which is to show the operator how much gas the vessel contains. It is a large glass conical funnel, made to fit into the upper end of the stop-cock, *a*.

The following is the method of using this air-holder. The first step is to fill it with water. For this the mouth, *c*, must be shut, and both the cocks, *a*, and *b*, opened. Water is then poured into the funnel, which running down the pipe, *d*, makes it escape through the holes in its bottom, and fills the vessel, while the common air makes its escape by the open cock, *b*. When the air-holder is quite full of water the cocks, *a* and *b*, are to be shut, the funnel, *h*, removed, and the stopper of the opening, *c*, removed. As the vessel is completely air-tight, the water cannot make its escape by the opening *c*, because the angle at which it enters the vessel prevents any common air from entering. The mouth of the pipe or cane connected with the apparatus for furnishing gas, being introduced into *c*, the gas rises gradually to the top of the air-holder, and the water runs out by the opening, *c*. When the process is finished this opening is to be stopped; and if the vessel be a good one, oxygen gas, hydrogen gas, or those of coal and oil, may be kept in it for many months without undergoing much alteration.

In order to transfer a portion of the gas out of this air-holder for any particular purpose, the point of the pipe, *f*, is to be introduced into the mouth of the vessel into which the gas is to be transferred, and then a quantity of water is poured into the glass funnel, *h*, which must be replaced for the purpose. The cocks, *a* and *b*, being opened, the water runs down the tube, *d*, and forces the oxygen gas to escape through the pipe, *f*. By this method the whole or any part of the gas may be transferred into other vessels.

If the distance between the funnel, *h*, and the cock, *a*, of the pipe, *d*, is increased by a pipe of two or three feet in length, then, if the funnel is filled as fast as it runs out, the pressure of the water in it will force out the gas, through the pipe, *f*, with considerable velocity.

Accum's Gasometer.

Fig. 102, represents this gasometor. Like the former, it is made of tin plate, is well japanned within and without. *A*, is the outer cylindrical vessel, with a lip at top. Two pipes, *d* and *e*, each fitted with a cock externally, are firmly soldered to the sides of the pail; the pipe, *d*, penetrates at the bottom of the pail, and proceeds to the centre, where it joins the termination of the pipe, *e*, which enters the top of the pail, and proceeds downwards; and, from the place of junction, the upright pipe, *g*, rises through the middle of the pail, a little above the level of its upper rim. The vessel, *b*, is a cylinder, open only at bottom, and of less diameter than the pail into which it is inverted, and can move up and down freely. This cylinder has a solid stem, *c*, which passes through a hole in the wooden cross bar of the frame, round the top of the pail, and serves both to keep the cylinder in a perpendicular direction when moving up and down, and to indicate the quantity of enclosed gas, by the scale of equal parts on its surface. The weight of the cylinder is counterpoised by weights put into a scale, which is connected with the top of the cylinder by a cord and pulley. The outer cylinder has besides an opening through its bottom, closed by a stopper, or cork, *f*, by which the water may be drawn off. The whole apparatus is conveniently supported on a heavy wooden stool.

To use this gas-holder, first let the inner cylinder fall to the bottom of the outer vessel, and pour water into the lip of the latter till it is quite full; then shut the cock, *e*, and open *d*, and connect this cock with the tube that carries the gas immediately from the retort, or other vessel in which it is produced, or, if more convenient, shut *d*, and convey the gas through *e*. The gas rises through the upright tube, *g*, to the top of the cylinder, *b*, which it gradually lifts up; and care must be taken to keep in the scale sufficient weight to allow the cylinder to move with perfect freedom. When all the gas is obtained, shut the cock, *d*, or *e*, and the gas may remain in the air-holder till wanted.

To take out any of it, connect with either of the stop-cocks a bent tube, and insert the mouth of it into a vessel destined to receive the gas; remove some of the weights out of the scale-dish, and open the stop-cock. The weight of the cylinder, *b*, will then press out the gas, and fill the vessel.

As the weight of the cylinder is constantly increasing during the whole of its rise out of the water, it is necessary to be continually adding weights to the scale-dish to compensate for this increase, otherwise the gas will be more and more compressed, and, at last, will cease to enter altogether. Or this increase may be still better compensated, by making the cord pass over a spiral pulley, as in Clayfield's quicksilver gasometer, by means of which, the weight in the scale-dish will act more and more powerfully as the cylinder rises, and thus compensate the increase of its weight.

These gas-holders may be used with a flexible pipe made of Indian rubber as hereafter described, for breathing oxygen gas, or any other as may be directed by the medical attendant; and either this or Watt's air-holder may have a blow-pipe attached to it.

Flexible Gas Pipes.

Mr. Skidmore tried leather pipes in various ways without success.

The guts of the hog and the bullock, in their natural state, answered the purpose tolerably for a short time, but they soon

Watt's Air-holder.

When the quantity of gas pr… some time in an infu… neous, notwithstanding … cessary to be provided with l… , tallow, or the like. … ready mentioned to contain … r this purpose, a worm of … of tin-plate japanned, or pa… as first made of the requisite … and they are known by t… twelve feet, by coiling the … or air-holders. around an iron rod: a covering … wound over this worm to serve …

Fig. 101, represents Mr. W… panned, both withinside an… which this is a representa… cylindrical vessel, close on… pressure of the atmosphe… cording to the changes … three openings, a, … as high up as possibl… with a cock, the o… bottom of the ves… of the air-holder … ber of holes … ground so as … is turned up … wise groov… tubes by … ture the … emain… near … whi… the … w… ber was cut into long narrow strips, … into two equal parts, and then re… as may be, into the shape of a circular … air of tailor's shears. These strips are … ering of tape or ferreting, also in a spiral … taken to place, as far as is practicable, the … in contact with each other, and to draw the … as to stretch the strips to two, three, or even … ir length. If a single bottle is not sufficient, … taken, and, for greater security, a double worm … ber may be wound one over the other. When … another covering of strong tape, linen tape is pre… to be wound spirally over the same, from end to … secured by another worm of very strong twine, laid as … d drawn as tight as possible. The iron rod is then to … drawn, the new-formed hose or pipe bent into a hoop by … g the two ends together, that it may be placed in a boil… water, and boiled for an hour or two; when it is to be ta… out, the outer covering of twine and tape taken off, and … wire worm and its tape or ferreting cover drawn out.

If this pipe is boiled a second time, its size is considerably reduced, which must be noticed when it is desired to join two of them together.

Hose or pipes of this kind have been said to have been manufactured upon glass or metal rods, but Mr. Skidmore was not able to succeed in that way, except upon short pipes not more than four inches long.

The pipes of Indian rubber made upon wire worms as here described, although not very elegant in their outward appearance, are very light, and do not allow the least leakage of gas.

APPARATUS FOR FITTING VESSELS.

Glass vessels, when issued from the manufacturers, frequently require to have a part of them cut off, or holes drilled in them before they are fit for use.

g off the Necks of Glass Vessels.

' of the necks of boltheads, matrasses, bo-
.nilar vessels, several modes have been

.hod a piece of thick leather is glued round
. place where it is to be cut off, and a mark is
.nd the neck with the edge of a flint, which is
rom slipping by the edge of the leather. This
es to guide the chemist in proceeding to cut off the
a three-cornered file. It often happens, that, as soon
file has made only a slight furrow round the neck, that
.ops off by the least touch; if it does not, the filing must
continued. This method is the best and surest manner of
ecting the purpose.

In the second method, a trace is first made by the flint, and
light furrow by the file, as in the former. A cotton thread
ped in oil of turpentine is then bound round the neck at the
row, and, being set on fire, the vessel is turned that the
k may be equally heated all round, and as soon as the oil
burned out, the place is touched with a drop of cold water,
ich generally causes the neck to fall off. Sometimes, how-
r, the vessel becomes cracked on the side, especially if the
rator is not accustomed to this work, and has not acquired
ne dexterity in it.

A third method is, after having made a furrow as before, to
e an iron ring that will fit the place, and heating it red hot,
ly steadily to the place for a few seconds, and if the neck
es not fall off, the ring is removed, and a drop of water put
the place by the finger, which generally succeeds very well,
t requires still more address to let all the circumference of the
g touch the glass at once. The chemists who use this me-
od have a stock of different sized rings for this purpose, but
me use a pair of tongs, moving on their middle part, and
ving different sized semicircles at their opposite ends.

The necks of vessels are also cut off by means of a copper
eel, with emery and oil; but this is a peculiar trade, and not
ed by chemists themselves.

In the first three methods above mentioned the edges of the
cks are sharp; and therefore it is necessary to file them, to
event them from cutting the fingers in fitting them to other
ssels.

M. Baumé having occasion for a great number of vessels for
e annual course of chemistry which he gave, along with Dr.
lacquer, for sixteen years, in each of which there were usu-
ly more than two thousand operations and experiments per-
rmed by him, as the demonstrator used the following me-
od to cut off the necks of two dozen large boltheads, or
her vessels, at once.

A line being stretched along a bench, or plank, the vessels were ranged so that the place where the necks were to be cut were all in the same line, the bowls of the vessels being placed alternately on one side and the other, that they might take up less room. A sufficient quantity of boiled plaster of Paris was then mixed with water, and the spaces between the necks filled up with it, that they might be kept in their places. The plaster being fixed, a saw, such as that used by the stone-masons, but small and light, was then employed, along with freestone grit and water, to cut through all the necks at once.

Piercing Glass and Stone-ware Vessels.

The most simple method of making a hole in the bowl of a glass bolthead, the arch of a retort, or the side of a receiver is, if possible, to pick out a place where there is a bubble in the glass. A very hard steel point is then taken, and worked round in the place, where it generally soon makes a hole down to the bubble; and by a repetition of the process, the hole is completed, which is then enlarged at pleasure, by a rat-tail file. Care must be taken that the file is smaller than the hole, for if it should stick in the hole, the endeavour to disengage it would certainly crack the glass.

Holes are made in the arch of stone-ware retorts, by putting them between the knees, and striking a hard steel point with a hammer, round the place where the hole is to be made, until an opening is effected, which is then enlarged by a rat-tail file, and finished for use by grinding a glass or stone-ware stopper in it, with sand and water, or emery and oil.

Dr. Lewis's method of making such holes for the insertion of barometer canes into glass receivers, was by pasting on the receiver a piece of thick leather, having a hole of the intended size cut in it, then filling the cavity with emery, and turning round in it a steel instrument, with a hollow in the point for retaining the emery, till the glass was worn through.

In Paris, there are workmen who pierce glass and stone-ware by a hollow drill, which cuts out a circular piece of the vessel. This succeeds very well when the hole is made several lines in diameter, but in making merely pin-holes, the workmen are apt to crack the glass: they succeed very well in making these small holes in stone-ware vessels.

The best method of drilling glass or porcelain, is stated to be the employment of a diamond point, set in brass, worked either by the hand, in an upright drill stock, or in a seal-engraver's engine. The latter way, perhaps, is preferable, as the mill will be more steady; but some thin oil must be used with the diamond.

In London, the chemists seldom have occasion for these operations, as they get them done by workmen who make it their business.

CHEMICAL LUTES.

The necessity of properly securing the joinings of chemical vessels, to prevent the escape of any of the products of processes or experiments, must be sufficiently apparent. For this purpose lutes are employed, which ought to be of such a nature, as to be impenetrable to the most subtle substance disengaged in the process.

Soft Wax.

This first object of lutes is very well accomplished by melting eight ounces of bees-wax, with about one ounce of turpentine. This lute is very easily managed, sticking very closely to glass, and is very difficultly penetrable. It may be rendered more consistent, and less or more hard, or pliable, by adding different kinds of resinous matters. Though this species of lute answers extremely well for retaining gases and vapours, there are many chemical experiments which produce considerable heat, by which the lute becomes liquified, and consequently the vapours escape.

This soft wax is also used to stop up the small hole left sometimes in receivers, employed in the distillation of substances yielding vapours which are very difficultly condensible. And also to make stoppers for bottles holding acid or volatile alkaline liquids, when stoppered bottles are not at hand.

Luting with Paper or Bladder.

In many cases it is considered sufficient to close the joints with slips of paper, on which some paste has been spread.

Slips of bladder, or gut skins, are also used, being simply moistened and bound round the joint with some twine; as they dry, they fit close and answer well, provided the vapours are not acid or saline.

Bladders close the joints still better, if they are soaked in water until they are quite rotten, stink intolerably, and stick to the fingers: they are then to be formed by the hands into rolls, and applied round the joints.

Paste Lute.

The common paste lute is made of linseed meal, (not ground linseed cake,) beat up with boiled starch. The French chemists use this lute to cover the corks with which bottles are stopped, and then, for greater security, cover it over with blotting-paper, dipped in carpenters' glue.

Cavendish used almond meal, (not ground almond cake,) beat up with a heavy hammer, along with carpenters' glue; this lute will resist the pressure of several inches of water.

Lime Lute.

This is much used, not only for closing the joints of vessels, but also for repairing glass and earthenware vessels, when they have been cracked by accident.

If cheese is used, it should be the driest sort, that it may be grated fine, then mixed with a little water, and some slaked lime: it is then spread quickly on strips of linen cloth, and applied, as it grows hard very quickly.

Some mix the slaked lime with white of egg and a little water, or with carpenters' glue, made sufficiently thin to remain liquid when cold, or with warmed size.

This lute is frequently used to cover the corks with which bottles are stopped; and the French chemists use it to smear over the corks before they are put into the necks of receivers, or other vessels.

This lute is generally capable of being taken off, by being wrapped round for some time with rags wetted with water, to which there may be added occasionally spirit of salt.

Fat Lute.

The following fat lute is the best hitherto discovered for securing the joints of vessels in which substances yielding vapours, very difficultly condensible are distilled, although not without some disadvantages. Very dry clay is put into a mortar, and well beaten with some boiled linseed oil: this lute is sometimes made with amber varnish, instead of boiled oil. To make this varnish, yellow amber is melted in an iron ladle, and mixed with linseed oil. Though the lute prepared with this varnish is supposed to be better than that made with boiled oil, yet, as its additional expense is hardly compensated by its superior quality, it is seldom used, except by those who estimate things by their cost.

The above fat lute is capable of sustaining a very violent degree of heat, is impenetrable by acid and spiritous liquor, and adheres exceedingly well to metal, stone-ware, or glass, provided they have been previously rendered perfectly dry. But if unfortunately any of the liquor in the course of an experiment gets through, either between the glass and the lute, or between the layers of the lute itself, so as to moisten the part, it is extremely difficult to close the opening. This is the chief inconvenience which attends the use of fat lute, and perhaps the only one it is subject to. As it is apt to soften by heat, all the junctures where it is used must be covered with slips of wet bladder applied over the luting, and fixed on by packthread tied round both above and below the joint; the bladder, and consequently the lute below, must be farther secured by a number of turns of packthread all over it. By these precautions we are free from

every danger of accident, and the junctures secured in this manner may be considered as perfectly closed.

It frequently happens, that the figure of the junctures prevents the application of packthread, and it often requires great address to apply the twine without shaking the apparatus, so that, where a number of junctures require luting, several are apt to be displaced while one is secured. In these cases, slips of linen, spread with lime lute, may be substituted, instead of the wet bladder. These are applied while still moist, and very speedily dry, and acquire considerable hardness. These fillets are usually applied likewise over junctures luted together with wax and rosin.

Before applying a lute, all the junctures of the vessels must be accurately and firmly fitted to each other so as not to admit of being moved. If the beak of a retort is to be luted to the neck of a receiver, they ought to fit pretty accurately, otherwise we must fix them by introducing short pieces of soft wood, or of cork. If the disproportion between the two be very considerable, a cork must be fitted into the neck of the receiver, having a circular hole of proper dimensions to admit the beak of the retort. The same precaution is necessary, in adapting bent tubes to the necks of bottles. And when one mouth is intended to admit two or more tubes, the cork must have two or three holes made in it, by a red hot iron, and enlarged by a rat-tail file.

When the whole apparatus is thus solidly joined, so that no part is loose, the application of the lute may be begun; and though this operation may appear extremely simple, yet it requires peculiar delicacy and management, as great care must be taken not to disturb one juncture whilst luting another, and more especially when applying the fillets and twine.

Before beginning any experiment, the closeness of the luting ought always to be previously tried, either by slightly heating the retort, or by blowing in a little air by some of the safety-pipes, as the alteration of pressure will cause a change in the level. If the joints be accurately luted, this alteration of level will be permanent; whereas, if there be the smallest opening in any of the junctures, the liquid will very soon recover its former level.

Coating.

Coating, or corication in the language of grandiloquent philosophers, is the covering of glass and stone-ware vessels with a thin coat of some substance to defend them from sudden alterations of temperature, as, when furnace doors are opened to put in fuel; or to enable glass vessels to keep their form when softened by heat.

The most usual lute is a mixture of about two avoirdupois pounds of clay that resists fire, one pound of some other clay

that is capable of being melted, two pounds of coarse sand, and an ounce of dry horse-dung, or chaff: the whole must be beaten up well with a little water.

To apply this lute, a lump is to be well worked in the hands, and formed into a plate on which the retort is to be placed, and the lute brought up all round it, so as to spread evenly about half an inch thick, as far as the middle of the neck, without any cracks or joinings. If the lute should happen to crack, or any joint be required, the lute must be taken off, and beaten up afresh.

The coating being applied, the retort is set by, that the coating may dry: when dry the outer surface is pared off so as to leave the coating about a quarter of an inch thick.

It is necessary that this coating should be somewhat fusible, that it may not come off in scales. If the fire is not intended to be very fierce, an ounce or two of litharge or red lead may be added to the mixture; or the coating, when dried, is painted over with litharge or red lead ground with linseed-oil.

Some make the mixture for the coating into cream or slip, by adding water, dip the retort into it, and turn it round to cover it equally, the retort is then held over a fire, to dry the coating; and this dipping and drying is repeated until the coating has acquired the desired thickness.

Mr. Willis preferred quicklime for his coating. He boiled two ounces of borax in half a pint of water, and added as much quicklime in fine powder as was sufficient to bring the mixture to the consistence of cream. With a painter's brush he covered the retort with this coating until it was about an eighth of an inch thick. When this coating was dry, he covered it in like manner with a thin paste of slaked lime and linseed-oil. This coating may even be used to mend retorts that crack during any operation.

In some authors may be found lists of the articles they think necessary to be procured by the chemist at the first fitting up of an experimental laboratory: but, as the views by which different persons are led to make experiments are infinitely various, so it is utterly impracticable to foresee what they may want.

There are, however, too points which cannot be too strongly impressed upon beginners. First, that they should purchase only those materials which they cannot possibly make themselves; since running the processes for obtaining the other articles will not only become a good introduction to the technical part, and show them the use of the different apparatus, but they will acquire a facility in experimenting, and be more con-

fident of the results. He who purchases ready-made preparations, and what are called tests, can only be looked upon as a half-and-half chemist, one degree above the mere reader of chemical books, but still far short of a really practical chemist.

Secondly, that the chemist should purchase no new apparatus, if he can possibly run the process with that which he has already got. A firm adherence to this rule will learn him to choose the most simple way of effecting his purpose. Scheele and Berzelius, the two most successful theoretical experimental chemists, are equally remarkable for the simplicity of their apparatus. Stahl, Lemeri, and Baumé, the three authors to whom practical chemistry is under the highest obligations, have all endeavoured to pursue the same economy, and to obtain their object in the simplest manner.

THEORY OF CHEMISTRY.

Doctrine of Definite Proportions.

Some substances unite in any proportion, as water and spirit of wine, others only in one proportion, called the point of saturation, as water and common salt: while a third class unite in several determinate proportions of one ingredient, which form a very simple progression, as 1, 1½, 2, 3, 4, 5, the other ingredient being taken as unity. The common salt of tartar, called by some salt of wormwood, and by others prepared kali, contains 275 parts by weight of carbonic acid, united with 594 parts of the base, potasse; whereas the supercarbonate, or bicarbonate, of potasse, called in general aerated kali, contains twice that proportion, that is 550 parts of carbonic acid, united to a similar proportion, or 594 parts of the potasse.

There are, indeed, some cases in which two ingredients unite in extremely different proportions; thus, iron united with about 1-120th of its weight of the carbonaceous element, is stated by Mr. Mushet to form soft cast steel; and, on the other hand, with about twenty-eight times its weight of the same carbonaceous element, it is supposed to form black lead.

It has been found, upon comparing the analogy of a number of substances composed of the same elements, that if the charge of one of these elements be considered as a fixed number, the charges of the other elements combined with it, will also denote the proportions in which they combine with one another, to form other substances, or at least some multiple, or very simple fraction of the same.

Oxygen, on account of its great aptitude to combine with

other bodies, has been generally chosen, by theoretical chemists of the Lavoisierian school, to form the root from which all the other proportional charges of the elements may be calculated.

This union of the elements in certain simple proportions is evident to the eye in the combination of the gases with each other, as also the contraction or expansion of volume that sometimes ensues in consequence of a chemical union taking place. Hence some have supposed that if solid bodies were reduced to a vaporous form, these vapours would unite either in equal volumes, or in certain simple proportions.

Henry, in Journal of Sciences, observes that the law of volumes is, to a certain extent, the expression of a general fact: but in regard to certain elementary substances, which are not known to us separately in a gaseous state, it is entirely a matter of inference that their vapours unite in volumes, which are either equal, or multiples, or submultiples of each other. Nor, if we admit the probability of such combinations, is there any decisive proof that the volumes which have been assigned are actually the true ones.

The theory of atoms is founded upon the general fact that bodies unite in definite proportions: and if we were to set out from a binary compound, whose gaseous elements exist in equal volumes, there would be a perfect accordance between the atomic hypothesis and the theory of volumes.

Some positions which have arisen out of the theory of volumes may or may not be true, without, in the latter case, impeaching its general correctness. Of this nature are the two following propositions:—

1. An increase in the density of a gas is supposed to indicate an increased number of simple atoms associated in the compound atom.

This may have been too hastily deduced, for olefiant gas, a compound of two atoms, is denser than carburetted hydrogen gas, a compound of three atoms. It is also inconsistent with Henry's views of the nitrous compounds.

2. The most simple compounds are the most difficult to be decomposed.

This stands as yet unimpeached:—though, if Mr. Dalton's opinion of nitrous gas being a compound of two atoms, be true, it would present a reasonable objection.

Dr. Henry conceives that nitrous oxide consists of two atoms, and those of nitrous gas of three; though the truth of the opinion is far from being demonstrated.

That the volumes of the elements of these two compounds are as stated by Gay Lussac, Dr. Henry entertains very little doubt: but he asks, do equal volumes of nitrogen gas and oxy-

gen gas contain, as Dalton supposes, equal numbers of atoms, or, as he takes to be more probable, do the same number of atoms exist in one volume of nitrogen gas as in two of oxygen gas?

The word proportion, used by Sir H. Davy, is ambiguous; the numbers 1 and 15 for hydrogen and oxygen were gained from the joint consideration of the weight and volume of the elements of water, those of 15 and 26, for oxygen and nitrogen from weight only; but the numbers for weights and volumes ought to be kept separate.

There are several different calculations of the relative proportions or charges in which the elements combine, of which those of Berzelius, Thenard, and Thomson, are the principal.

Thenard has constructed his table upon the plan the best adapted for practice; and is therefore given in detail; the numbers of Berzelius and Thomson for the elements themselves are only noticed in this place. To these tables are annexed Berzelius' mode of marking the chemical composition in characters. A most capital invention, which may justly be esteemed equal to that of the Arabian figures in arithmetic, or the musical notes. In this chemical algorithm, the numbers to the right of the sign of an element, or the superior figures to the left denote how many proportions, atoms, volumes, or charges, of that element, are contained in the compound. X is used, as in algebra, to denote an unknown quantity, and compounds acting as elements are enclosed in a parenthesis.

Thenard's Proportional Numbers.

Proportional numbers of chemical bodies are those which point the proportion in which they combine with each other.

The following table was calculated by Mr. Despretz, and principally taken from Berzelius' tables.

1. *Oxygen.* O, or ·

The single charge of oxygen is considered as 10,000, and from thence the proportional weight of the single charge of all other bodies is computed.

In the original table of Thenard, as also in those of Berzelius, and other authors, the numbers are given partly in whole numbers, and partly accompanied with decimal fractions of three or four places of figures: but they are now printed in integral numbers, as affording the generality of practical chemists, little accustomed to fractional expressions, a clearer view of the proportions.

2. *Unmetallic Substances, not hitherto divided into two or more simpler Substances*

17,705 of *Azote*, Az combined

with	forms
10,000 of oxygen.	27,705 protoxide of azote, Az·
20,000 . .	37,705 deutoxide of azote, Az·

with		forms
30,000	. .	47,705 hyponitrous acid, Az··
40,000	. .	57,705 nitrous acid, Az:.
50,000	. .	67,705 nitric acid, Az::·

67,705 of nitric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral nitrate.

with		forms
50,000 of oxygen and 11,243 of water		78,948 concentrated nitric acid, Az::· H·
15,310 of carbone		33,015 cyanogen, Az C
3,750 of hydrogen		21,455 ammoniac, Az H^3

21,455 of ammoniac is substituted for so much basis as contains 10,000 of oxygen, in the composition of ammoniacal salts.

6,965 of *Bore*, B.

20,000 of oxygen	26,965 boracic acid, B:

26,965 of boracic acid combined with so much of any basis as contains 10,000 of oxygen, forms a borate.

20,000 of oxygen and 44,972 of water	71,937 crystallized boracic acid, B: H^4

7,655 of *Carbone*, C.

10,000 of oxygen	17,655 oxide of carbone, C·
20,000 . .	27,655 carbonic acid, C·

27,655 of carbonic acid combined with so much of any basis as contains 10,000 of oxygen, forms a subcarbonate.

55,311 of carbonic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral carbonate.

44,013 of chlore	51,668 protochlorure of carbone, C Cl
66,020 ($1\frac{1}{2}$) .	73,675 deutochlorure of carbone, 2 C Cl^3
1,243 of hydrogen	8,898 protocarboned hydrogen, CH
2,486 . .	10,141 deutocarboned hydrogen, CH^2

44,013 of *Chlore*, Cl.

10,000 of oxygen	54,013 protoxide of chlore, Cl·
40,000 . .	84,013 deutoxide of chlore, Cl::
50,000 . .	94,013 chloric acid, Cl::·

94,013 of chloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral chlorate.

70,000 . .	114,013 perchloric acid, Ch::::·

114,013 of perchloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral perchlorate.

17,655 oxide of carbone. .	61,668 chloroxicarbonic acid, Ch C·
1,243 of hydrogen	45,256 hydrochloric acid, Ch H

45,256 of hydrochloric acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral hydrochlorate.

1,243 of *Hydrogen*, H.

10,000 oxygen .	11,243 water H·
20,000 . .	21,243 deutoxide of hydrogen, H:

156,223 of *Iodine*, I.

50,000 oxygen .	206,223 iodic acid, I::·

206,232 of iodic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral iodate.

1,243 hydrogen.	157,466 hydroiodic acid, IH

157,466 of hydroiodic acid combined with so much of any basis as contains 10,000 of oxygen, forms a neutral hydroiodate.

5,901 azote. ($\frac{1}{3}$) .	163,123 iodure of azote, 3 I Az

19,615 of *Phosphorus*, P.

with	forms
7,500 oxygen ($\frac{1}{2}$)	26,615 hypophosphorous acid, 2 PO
15,000 ($1\frac{1}{2}$) .	34,615 phosphorous acid, 2 PO^3

34,615 of phosphorous acid with so much of any basis as contains 10,000 of oxygen, forms a neutral phosphate.

25,000 ($2\frac{1}{2}$) . . 44,615 phosphoric acid, 2 PO^5

44,615 of phosphoric acid with so much of any basis as contains 10,000 of oxygen, forms a neutral phosphate.

As for the sub-phosphates, the acidulous phosphates, or the acid phosphates, the number 44,615 of phosphoric acid must be multiplied by $\frac{2}{3}$, $\frac{3}{4}$, or by 2, the quantity of the base remaining the same.

66,020 chlore ($1\frac{1}{2}$) 85,635 proto chlorure of phosphorus
2 P Cl^3

110,033 ($2\frac{1}{2}$) . 129,648 deuto chlorure of phosphorus,
2 P Cl^5

49,591 of *Selenium*, Se.

20,000 oxygen . 69,591 selenic acid, Se·

69,591 of selenic acid with as much of any basis as contains 10,000 of oxygen, forms a neutral seleniate.

1,243 hydrogen 50,634 hydro selenic acid, SH

20,000 of *Sulphur*, S.

10,000 of oxygen 30,000 hyposulphurous acid, S·
20,000 . . 40,000 sulphurous acid, S:

40,000 of sulphurous acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral sulphate.

25,000 ($2\frac{1}{2}$) . 45,000 hyposulphuric acid, 2 S O^5

90,000 of hyposulphuric acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral hyposulphate.

30,000 . . 50,000 sulphuric acid, S:·

50,000 of sulphuric acid, with so much of any basis as contains 10,000 of oxygen, forms a neutral sulphate.

30,000 oxygen and 11,243 of water 61,243 concentrated sulphuric acid, S:· H·

1,243 of hydrogen 21,243 hydro-sulphuric acid, S H

21,243 of hydro-sulphuric acid, with so much of any base as contains 10,000 of oxygen, forms a sub hydro-sulphate. It takes 42,486 of hydro-sulphuric acid to form saturated hydro-sulphates.

3. *Metallic Substances not hitherto divided into two or more simpler substances.*

11,410 of *Aluminium*, Al

10,000 oxygen 21.410 alumine, Al·

53,760 of *Antimony*, Sb.

10,000 of oxygen 63,760 protoxide of antimony, Sb·
13,333 ($1\frac{1}{3}$) . 67,090 deutoxide of antimony, 3 Sb O^4
16,663 ($1\frac{2}{3}$) . 70,420 tritoxide of antimony, 3 Sb O^5
44,013 chlore . 97,773 proto chlorure of antimony, Sb Cl
20,000 sulphur . 73,760 proto sulphure of antimony, Sb S
156,223 iode . 209,983 proto-iodure of antimony, Sb I

47,038 of *Arsenic*, As.

15,000 of oxygen ($1\frac{1}{2}$) 62,038 oxide of arsenic, or arsenous acid,
2 As O_3

25,000 ($2\frac{1}{2}$) . 72,038 arsenic acid, 2 As O^5

72,038 of arsenic acid with so much of any basis as contains 10,000 of oxygen, forms a neutral arseniate.

with forms

20,000 of sulphur		67,038 proto sulphure of arsenic, As S
30,000	. .	77,038 deuto sulphure of arsenic, 2 As S^2
66,020 chlore	(1½)	113,058 chlorure of arsenic, 2 As Cl^3
234,334 iode	(1½)	281,342 iodure of arsenic, 2 As I^3

85,690 of *Barium*, Ba.

10,000 oxygen	.	95,690 barytes, Ba·
20,000	. .	105,690 deutoxide of barium, Ba:
20,000 sulphur	.	105,690 proto-sulphure of barium, Ba S
44,010 chlore	.	129,700 chlorure of barium, Ba Cl
156,223 iode	.	141,913 iodure of barium, Ba I

88,690 of *Bismuth*, Bi.

10,000 oxygen	.	98,690 oxide of bismuth, Bi·
20,000 sulphur	.	108,690 sulphure of bismuth, Bi S
44,010 chlore	.	132,700 chlorure of bismuth, Bi Cl
156,223 iode	.	244,913 iodure of bismuth, Bi I

69,680 of *Cadmium*, Cm.

10,000 oxygen	.	79,680 oxide of cadmium, Cm·
20,000 sulphur	.	89,680 sulphur of cadmium, Cm S

25,600 of *Calcium*, Ca.

10,000 oxygen	.	35,600 lime, Ca·
20,000	. .	45,600 deutoxide of calcium, Ca:
20,000 sulphur	.	45,600 proto sulphure of calcium, Ca S
44,013 chlore	.	69,613 chlorure of calcium, Ca Cl
156,223 iode	.	181,823 iodure of calcium, Ca I

57,470 of *Cerium*, Ce.

10,000 oxygen	.	67,470 protoxide of cerium, Ce·
15,000 (1½)	.	72,470 deutoxide of cerium, 2 Ce O^3
44,013 chlore	.	101,483 proto chlorure of cerium, Ce Cl

35,180 of *Chromium*, Ch.

15,000 oxygen	(1½)	50,180 oxide of chromium, 2 Ch O^3
20,000	. .	55,180 deutoxide of chromium, Ch:
30,000	. .	65,180 chromic acid, Ch:·

65,180, of chromic acid with so much of any basis as contains 10,000 oxygen, forms a neutral chromate.

36,900 of *Cobalt*, Co.

10,000 oxygen	.	46,900 protoxide of cobalt, Co·
15,000 (1½)	.	51,900 deutoxide of cobalt, 2 Co O^3
44,013 chlore	.	80,913 protochlorure of cobalt, Co Cl

182,310 of *Columbium*, Ta.

10,000 oxygen . 192,310 columbic acid, Ta·

192,310 of columbic acid with so much of any basis as contains 10,000 oxygen, forms a neutral columbate.

79,140 of *Copper*, Cu.

10,000 oxygen	.	89,140 protoxide of copper, Cu·
20,000	. .	99,140 deutoxide of copper, Cu:
40,000	. .	110,140 tritoxide of copper, Cu::
20,000 sulphur	.	99,140 proto sulphure of copper, Cu S
40,000	. .	119,140 deuto sulphure of copper, Cu S^2
44,013 chlore	.	123,153 proto chlorure of copper, Cu Cl
88,026	. .	167,166 deuto chlorure of copper, Cu Cl^2
156,223 iode	.	235,363 iodure of copper, Cu I

22,080 of *Glucinium*, Be.

th forms

10,000 oxygen . 32,080 glucine, Be·

248,600 of *Gold*, Au.

10,000 oxygen . 258,600 protoxide of gold, Au·
30,000 . . 278,600 deutoxide of gold, Au:·
40,000 sulphur . 288,600 sulphure of gold, Au S^2
132,039 chlore . 380,639 chlorure of gold, Au Cl^3

60,000 of *Iridium*, Ir.

20,000 sulphur . 60,000 sulphure of iridium, Ir S

33,920 of *Iron*, Fe.

10,000 oxygen . 43,920 protoxide of iron, Fe·
15,000 . . 48,920 peroxide of iron, 2 Fe O^3
20,000 sulphur . 53,920 proto sulphure of iron, Fe S
40,000 . . 73,920 per sulphure of iron, Fe S^2
44,013 chlore . 77,933 proto chlorure of iron, Fe Cl
156,223 iode . 190,143 proto iodure of iron, Fe I

129,450 of *Lead*, Pb.

10,000 oxygen . 139,450 protoxide of lead, Pb·
15,000 (1½) . 144,450 deutoxide of lead, 2 Pb O^3
20,000 . 149,450 tritoxide of lead, Pb:
20,000 sulphur . 149,450 proto sulphure of lead, Pb S
44,013 chlore . 173,463 chlorure of lead, Pb Cl
156,223 iode . 285,673 iodure of lead, Pb I

12,780 of *Lithium*, L.

10,000 oxygen . 22,780 lithine, L·
44,013 chlore . 56,793 chlorure of lithium, L Cl

15,840 of *Magnesium*, Mg.

10,000 oxygen . 25,840 magnesia, Mg·
44,013 chlore . 59,853 chlorure of magnesium, Mg Cl
156,223 iode . 172,063 iodure of magnesium, Mg I

35,580 of *Manganese*, Mn.

10,000 oxygen . 45,580 protoxide of manganese, Mn·
15,000 (1½) . 50,580 deutoxide of manganese, 2 Mn. O^3
20,000 . . 55,580 peroxide of manganese, Mn:·
44,013 chlore . 79,593 chlorure of manganese, Mn Cl

59,680 of *Molybdene*, Mo.

10,000 oxygen . 69,680 oxide of molybdene, Mo·
20,000 . . 79,680 molybdene acid, Mo:
30,000 . . 89,680 molybdic acid, Mo:·

),680 of molybdic acid with so much of any base as contains 10,000 of oxy-, forms a neutral molybdate.

40,000 sulphur . 99,680 sulphure of Molybdene, Mo S^2

36,970 of *Nickel*, Ni.

10,000 . . 46,970 protoxide of nickel, Ni·
15,000 (1½) . 51,970 peroxide of nickel, 2 Ni O^3
44,013 chlore . 80,983 chlorure of nickel, Ni Cl

Osmium, proportional number unknown.

70,380 of *Palladium*, Pa.

10,000 oxygen . 80,386 protoxide of palladium, Pa·
20,000 sulphur . 90,380 sulphure of palladium, Pa S
44,013 chlore : 114,393 chlorure of palladium, Pa Cl

121,520 of *Platinum*, Pt.

10,000 oxygen . 131,520 protoxide of platinum, Pt·

with		forms
20,000	.	141,520 deutoxide of platinum, Pt:
88,026 chlore	.	209,546 chlorure of platinum, Pt Cl^2
20,000 sulphur	.	141,520 proto sulphure of platinum, Pt S
40,000	.	101,520 deuto sulphure of platinum, Pt S^2

48,990 of *Potassium*, K.

10,000 oxygen	.	58,990 potasse, K·
30,000	.	78,990 peroxide of potassium, K:·
44,013 chlore	.	93,003 chlorure of potassium, K Cl
156,220 iode	.	205,210 iodure of potassium, KI
20,000 sulphur	.	68,990 proto sulphure of potassium, KS

253,160 of *Quicksilver*, Hd.

10,000 oxygen	.	263,160 protoxide of quicksilver, Hd·
20,000	.	273,160 deutoxide of quicksilver, Hd:
20,000 sulphur	.	273,160 proto sulphure of quicksilver, Hd S
40,000	.	293,160 deuto sulphure of quicksilver, Hd S^2
44,013 chlore	.	297,173 chlorure of quicksilver, Hd Cl
88,026	.	341,186 deuto chlorure of quicksilver, Hd Cl^2
156,220 iode	.	409,380 iodure of quicksilver, HI
312,440	.	565,600 deuto iodure of quicksilver, HI^2

150,010 of *Rhodium*, R.

10,000 oxygen	.	160,010 protoxide of rhodium, R·
20,000	.	170,010 deutoxide of rhodium, R:
30,000	.	180,010 tritoxide of rhodium, R:·
40,000 sulphur	.	190,010 sulphure of rhodium, RS^2

9,890 of *Silicium*, Si.

10,000 oxygen	.	19,890 silica, Si·

135,160 of *Silver*, Ag.

10,000 oxygen	.	145,160 oxide of silver, Ag·
20,000 sulphur	.	155,160 sulphure of silver, Ag S
44,013 chlore	.	179,173 chlorure of silver, Ag Cl
156,223 iode	.	291,383 iodure of silver, Ag I

29,090 of *Sodium*, Na.

10,000 oxygen	.	39,090 soda, Na·
15,000 ($1\frac{1}{2}$)	.	45,090 peroxide of sodium, 2 $Na O^3$
20,000 sulphur	.	49,090 proto sulphure of sodium, Na S
44,013 chlore	.	73,103 chlorure of sodium, Na Ch
156,223 iode	.	185,313 iodure of sodium, Na I

54,730 of *Strontium*, Sr.

10,000 oxygen	.	64,730 strontian, Sr·
20,000	.	74,730 deutoxide of strontium, Sr:
20,000 sulphur	.	74,730 proto sulphure of strontium, Sr S
44,013 chlore	.	98,743 chlorure of strontium, Sr Cl
156,223 iode	.	210,953 iodure of strontium, Sr I

40,320 of *Tellurium*, Te.

10,000 oxygen	.	50,320 oxide of tellurium, Te·
44,013 chlore	.	88,333 chlorure of tellurium, Te Cl
1,243 hydrogen	.	41,563 telluretted hydrogen, Te H

73,530 of *Tin* Sn.

10,000 oxygen	.	83,530 protoxide of tin, Sn·
20,000	.	93,530 deutoxide of tin, Sn:
20,000 sulphur	.	93,530 proto sulphure of tin, Sn S
40,000	.	113,530 per sulphure of tin, Sn S^2
44,013 chlore	.	117,543 proto chlorure of tin, Sn Cl

forms

88,026 . . 161,556 deuto chlorure of tin $Sn Cl^2$
156,223 iode . . 229,753 iodure of tin, Sn I

Titanium, Ti. proportional number unknown.

120,770 of *Tungsten*, W.

20,000 oxygen . 140,770 oxide of tungsten, W:
30,000 . . 150,770 tungstic acid, W:·

150,770 of tungstic acid, with so much of any basis as contains 10,000 ;en, forms a tungstate.

40,000 sulphur . 160,770 sulphure of tungsten, WS^2

157,340 of *Uranium*, U.

10,000 oxygen . 167,340 protoxide of urane, U·
15,000 ($1\frac{1}{2}$) . 172,340 deutoxide of urane, 2 U O^3

40,260 of *Yttrium*, Y.

10,000 oxygen . 50,260 yttria, Y·

40,320 of *Zinc*, Zn.

10,000 oxygen . 50,320 oxide of zinc, Zn·
20,000 sulphur . . 60,320 sulphur of zinc, Zn S.
44,013 chlore . 84,333 chlorine of zinc, Zn Cl
156,223 iode . 196,543 iodure of zinc, Zn I

46,250 of *Zirconium*, Zr.

10,000 oxygen . 56,250 zircone, Zr^6

64,115 Acetic acid, A-
150,950 Benzoic acid, B-
72,780 Citric acid, C-
46,390 Formic acid, F·
79,180 Gallic acid, G-
33,960 Hydro-cyanic acid, P-
91,160 Malic acid, Ml-
333,333 Margaric acid, Mg-
131,830 Mucic acid, Mu-
333,333 Oleic acid, Ol-
45,170 Oxalic acid, O-
62,780 Succinic acid, S-
83,450 Tartaric acid, T-

ll respectively with so much of any base as contains 10,000 of oxygen, form utral salt.

11,243· *Water*, H·

21,410 alumine, Al· 32,653 hydrate of alumine, Al· H·
95,690 barytes, Ba· 106,933 hydrate of barytes, Ba· H·
35,600 lime, Ca· 46,843 hydrate of lime, Ca· H·
99,140 deutoxide of copper, Cu: 10,383 hydrate of deutoxide of copper, Cu: H·
83,530 protoxide of tin, Sn· 94,773 hydrate of protoxide of tin, Sn· H·
43,920 protoxide of iron, Fe· 55,163 hydrate of protoxide of iron, Fe· H·
22,780 lithine, L· 34,023 hydrate of lithine, L· H·
25,840 magnesia, Ma· 37,083 hydrate of magnesia Ma· H·
45,580 protoxide of manganese, Mn· 56,823 hydrate of protoxide of manganese, Mn· H·
58,990 potasse, K· 70,233 hydrate of potasse, K· H·
39,090 soda, Na· 50,333 hydrate of soda, Na· H·
64,730 strontia, Sr· 75,973 hydrate of strontia, Sr· H·
50,320 oxide of zinc, Zn· 61,583 hydrate of oxide of zinc, Zn· H·

In these hydrates, which are the greatest part of those in which the proportion of water has been accurately determined, the quantity of oxygen in the oxide is equal to that in the water, on the Lavoisierian hypothesis.

It is probable that there exists subhydrates which contain only half this proportion of water; and superhydrates which contain twice this proportion or even more. The crystallized hydrates of potasse, soda, barytes, and strontia are probably super hydrates. Berzelius is of opinion that crystallized hydrate of barytes contains one proportion of barytes and nine of water, or Ba· + 9 H·

with	forms
64,110 dry acetic acid, A-	75,353 crystallized acetic acid, A - H·
23,453 dry tartaric acid, T-	94,693 crystallized tartaric acid, T - H·
113,680 dry acetate of deutoxide of copper, A - Cu:	124,923 crystallized acetate of deutoxide of copper, A - Cu: + H·
76,754 dry bicarbonate of ammoniac, 2 C: + Az H³	87,997 crystallized bicarbonate of ammoniac, 2 C: + Az H³ + H·
114,300 dry bicarbonate of potasse, 2 C: K·	125,543 crystallized bicarbonate of potasse, 2 C: K· + H·
94,400 dry bicarbonate of soda, 2 C: Na·	105,643 crystallized bicarbonate of soda, 2 C: Na· + H·
89,149 dry nitrate of ammoniac, Az::· + Az H³	100,392 crystallized nitrate of ammoniac, Az::· + Az H³ + H·
149,350 dry bi-oxalate of potasse, 2 O - K·	160,593 crystallized bi-oxalate of potasse, 2 O - K· + H·
110,684 dry bi-phosphate of ammoniac, 2 (P O$^{2\cdot5}$) + Az H³	144,413 crystallized bi-phosphate of ammoniac, 2 (P O$^{2\cdot5}$) Az H³ + H·
225,850 dry bi-tartrate of potasse, 2 T - K·	237,155 crystallized bi-tartrate of potasse, 2 T - K· + H·

16,864 Water, 1·5 H·

48,920 peroxide of iron, Fe O$^{1\cdot5}$	65,784 hydrate of peroxide of iron, Fe O$^{1\cdot5}$ + 1·5 H·
93,482 dry arseniate of ammoniac, As O$^{2\cdot5}$ + Az H³	110,346 crystallized arseniate of ammoniac, As O$^{2\cdot5}$ + Az H³ + 1·5 H·
66,064 dry phosphate of ammonic, P O$^{2\cdot5}$ + Az H³	82,928 crystallized phosphate of ammoniac, P O$^{2\cdot5}$ + Az H³ 1·5 H·

22,480 Water, 2 H·

72,780 dry citric acid, C-	95,260 crystallized citric acid, C- + 2 H·
203,066 dry biarseniate of potasse, 2 (As O$^{2\cdot5}$ + K·	225,552 crystallized biarseniate of potasse, 2 (As O$^{2\cdot5}$) + K· + 2 H·
185,690 dry hypo-sulphate of barytes, S O$^{2\cdot5}$ + Ba·	207,976 crystallized hypo-sulphate of barytes, S O$^{2\cdot5}$ + Ba· + 2 H·
148,230 dry biphosphate of potasse, 2 (P O$^{2\cdot5}$) + K·	170,716 crystallized biphosphate of potasse, 2 (P O$^{2\cdot5}$) + K· + 2 H·

	forms
71,444 dry sulphate of ammoniac, S:· + Az H³	93,930 crystallized sulphate of ammoniac, S:· + Az H³ + 2 H·
85,600 dry sulphate of lime, S:· Ca·	108,080 hydrated crystals of sulphate of lime, S:· Ca· + 2 H··

33,729 Water, 3 H·

203,560 dry acetate of lead, A- Pb·	237,289 crystallized acetate of lead, A-Pb· + 3 H·
165,520 dry biarseniate of ammoniac, 2 (As O$^{2.5}$) + Az H³	199,249 crystallized biarseniate of ammoniac, 2 (As O$^{2.5}$) + Az H³ + 3 H·
239,710 dry quadroxalate of potasse, 4 O - K·	273,439 crystallized quadroxalate of potash, 4 O - K· + 3 H·
110,684 dry biphosphate of ammoniac, 2 (PO$^{2.5}$) + Az H³	144,413 crystallized biphosphate of ammoniac, 2 (PO$^{2.5}$) + Az H³ + 3 H·

44,972 Water, 4 H·

183,166 dry biarseniate of soda, 2 (As O$^{2.5}$) + Na·	228,138 crystallized biarseniate of soda, 2 (As O$^{2.5}$) + Na· + 4 H·
128,330 dry biphosphate of soda, 2 (PO$^{2.5}$) + La·	173,302 crystallized biphosphate of soda, 2 (PO$^{2.5}$) + Na· + 4 H·

56,215 Water, 5 H·

149,140 dry sulphate of deutoxide of copper, S:· Cu:	205,355 crystallized sulphate of deutoxide of copper, S:· Cu: + 5 H·
100,320 dry sulphate of zinc, S:· Zn·	156,355 crystallized sulphate of zinc, S:· Zn· + 5 H·

78,701 Water, 7 H·

93,920 dry sulphate of protoxide of iron, S:· Fe·	172,621 crystallized sulphate of protoxide of iron, S:· Fe· + 7 H·
75,840 dry sulphate of magnesia, S:· Mg·	154,541 crystallized sulphate of magnesia, S:· Mg· + 7 H·
96,970 dry sulphate of nickel, S:· N 2·	175,671 crystallized sulphate of nickel, S:· Ni· + 7 H·

112,430 Water, 10 H·

66,745 dry carbonate of soda, C: Na·	179,175 crystallized carbonate of soda, C: Na· + 10 H·
89,090 dry sulphate of soda, S:· Na·	201,520 crystallized sulphate of soda, S:· Na· + 10 H·

134,916 Water, 12 H·

111,128 dry arseniate of soda, As O$^{2.5}$ + Na·	246,044 crystallized arseniate of soda, As O$^{2.5}$ + Na· + 12 H·
83,710 dry phosphate of soda, PO$^{2.5}$ + Na·	218,626 crystallized phosphate of soda, PO$^{2.5}$ + Na· + 12 H·

In this table the proportional number or charge of any substance is estimated, so that it requires 10,000 of oxygen to reduce it to a protoxide, except in the case of bore, phosphorus, iode, arsenic, chromium, and tungsten, for in these cases, that number has been chosen which will enable their acids to saturate a base containing 10,000 of oxygen. By this arrangement, a very considerable degree of facility in making calculations in practical chemistry has been obtained.

To obtain the proportional numbers of the neutral salts, it is therefore only necessary to add the number of the acid, to that of the base that contains 10,000 of oxygen, as 64,110 acetic acid, with 139,450 protoxide of lead, forms 203,560 dry acetate of lead, which, in its hydrated or crystalline state, is called sugar of lead, or lead saccharum.

The proportional numbers of the neutralized deutoxides is obtained by observing that they require so much the larger proportion of acid as they contain oxygen, as 263,160 protoxide of quicksilver, containing 10,000 of oxygen, requires only 50,000 of dry sulphuric acid for its neutralization, but 273,160 deutoxide of quicksilver, containing an extra 10,000 of oxygen, requires twice as much, or 100,000 of dry sulphuric acid to neutralize it. In general, super-salts, or those with excess of acid, contain twice as much acid as neutral salts; and sub-salts, or those with excess of base, contain only half as much acid as neutral salts; but there are many exceptions to this rule, and it is always the safest plan to consult the particular article.

Use of the Proportional Numbers.

This is best shown by examples.

1. How much charcoal, supposing it composed of pure carbone, is necessary to reduce a pound of the protoxide of any metal, as of iron, so that the charcoal may, by uniting with the oxygen gas, form carbonic oxide.

17,655 carbonic oxide gas contains 10,000 of oxygen, and 43,920 black oxide of iron the same quantity; consequently, 7,655 parts of charcoal, will absorb all the oxygen of 43,920 parts of black oxide of iron, and form carbonic oxide gas. Therefore, rejecting the three right-hand figures, as subtleties of little use in practice, say, if 44 black oxide of iron requires 8 of charcoal, 1 pound, or 7000 grains, of the metallic oxide, will require 1272 grains, or three ounces, three quarters, and fifteen grains. If it was intended to produce carbonic acid gas, which contains twice as much oxygen, it would, of course, be only necessary to use half that quantity of charcoal.

2. In what proportion must nitrate of lime, and sub-carbo-

nate of potasse be mixed, that there may occur a complete exchange of their acids and bases?

In all these cases, the proportional numbers of the salts are themselves the answer to the question: consequently, as 67,705 nitric acid, with 35,600 lime, forms 103,305 nitrate of lime, and 27,655 carbonic acid with 58,990 potasse, forms 86,645 sub-carbonate of potasse; therefore 104 parts nitrate of lime, will require 87 of subcarbonate of potasse, to change them into nitrate of potasse, or saltpetre, and 127 parts of that salt will be produced by the union of the 68 parts of nitric acid with the 59 of potasse.

3. What quantity of zinc will precipitate the copper from 50 avoirdupois ounces of blue vitriol, or crystallized sulphate of the deutoxide of copper?

The number for blue vitriol is 203,355, which contains 56,215 of water, and only 149,140 of dry sulphate, composed of 50,000 dry sulphuric acid and 99,140 of deutoxide of copper, which, as it contains 20,000 of oxygen, will of course require two proportions, or 80,640 of zinc. Now, if 204 blue vitriol requires 81 of zinc, 50 ounces will require 19 to precipitate the copper.

4. How much oil of vitriol is required to expel all the nitric acid from one pound of saltpetre?

Saltpetre is composed of 67,705 nitric acid, and 58,990 of potasse, consequently its number is 126,695; now 58,990 of potasse, as it contains 10,000 of oxygen, is neutralized by 50,000 of dry sulphuric acid, or 61,243 of the hydrated acid, called oil of vitriol; therefore, 127 parts of saltpetre will require 62 of oil of vitriol, and, consequently, a pound will require very nearly half a pound of the oil of vitriol.

5. How much oil of vitriol and common salt is necessary to convert 20 avoirdupois pounds of quicksilver into corrosive sublimate, and what quantity of sublimate will they produce?

In this operation the quicksilver must be heated with the sulphuric acid to form sulphate of deutoxide of quicksilver, which will require four proportions of dry acid, namely, two to oxidate the quicksilver, by means of their own change into sulphurous acid, and two to unite with the deutoxide thus formed and neutralize it; by which there will be obtained a sulphate composed of 100,000 of dry sulphuric acid, and 273,160 of deutoxide of quicksilver.

As the deutoxide of quicksilver contains two proportions of oxygen, it will require two of common salt for its decomposition; now two of sodium are 58,180, and two of chlore are 88,026, forming 146,206 of common salt.

The 58,180 of sodium will absorb two proportions, or 20,000 of oxygen, and unite with two proportions, or 100,000 of dry

sulphuric acid, and thus form 178,180 of dry sulphate of soda. The 88,026 of chlore will combine with one proportion, or 253,160 of quicksilver, and form 341,186 of deutochlorure, or the corrosive sublimate of quicksilver.

If, therefore, 253 of quicksilver require four proportions, or 200 of dry sulphuric acid, which are equivalent to 245 of oil of vitriol, twenty av. pounds of quicksilver will require nineteen pounds .36 of that acid, the fraction being equal to rather more than five ounces and three-quarters.

Secondly, if 253 of quicksilver require 146 of common salt, twenty av. pounds will require 11.54, or rather more than eleven pounds and a half.

Lastly, if 253 of quicksilver produce 341 of corrosive sublimate, twenty av. pounds will produce 26.95, or nearly twenty-six pounds fifteen ounces and a quarter.

Dr. Wollaston has laid down the numbers of the most usual substances occurring in the practice of chemistry on a sliding scale of artificial numbers, by which persons versed in the use of a sliding rule may solve the problems of this kind that most frequently occur, by inspection: but this instrumental arithmetic only tends to prevent persons from acquiring a facility in calculation, and is, therefore, in the long run, a hindrance rather than a help.

The symbols used by the chemists to express the theoretical composition of bodies, being taken from their foreign Latin names, do not always accord with the English: an alphabetical list of them is here given, and to each of them is annexed Berzelius' and Thomson's proportional numbers.

		Berzelius.	Thomson.
A-	Acetic acid	641,120	6,250
Al	Aluminium	312,330	1,250
	Alumine	642,330	2,250
Aq	Water	112,435	1,125
Ag	Silver	2,703,210	13,750
As	Arsenic	940,770	4,750
	Arsenic acid	1,440,770	7,750
Au	Gold	2,486,000	25,000
Az	Azote	N·	1,750
Ba	Barium	1,713,860	8,750
	Barytes	1,913,860	9,750
B-	Benzoic acid	1,509,550	15,000
Be	Beryllium: or glucinium	662,560	2,250
	Berylla, or glucine	962,560	3,250
Bi	Bismuth	1,773,800	9,000
B	Bore or boron	69,655	1,000
Ca	Calcium	512,060	2,500
	Lime	712,060	3,500
C	Carbone	75,330	750
Ce	Cerium	1,149,440	6,250
Ch	Chrome	703,640	3,500
Cl	Chlorine	M:·	4,500
C-	Citric acid	727,850	7,250

		Berzelius.	Thomson.
Co	Cobalt	738,000	3,250
Cu	Copper	791,391	4,000
Fe	Iron	678,430	3,500
Fl	Fluoricum	75,030	2,250?
	Fluoric acid	275,030	1,250?
F-	Formic acid	463,930	4,625
G-	Gallic acid	791,780	7,750?
Hg	Quicksilver	2,531,600	25,000
H	Hydrogen	6,217	125
I	Iodicum	1,266,700	——
	Iodine	1:-	15,500
Ir	Iridium	——	3,750
K	Kalium, or potassium	979,830	5,000
	Kali, or potassium	1,179,830	6,000
L	Lithium	255,630	1,250
Mg	Magnesium	316,720	1,500
	Magnesia	516,720	2,500
Mn	Manganese	711,570	3,500
Mo	Molybdenum	596,800	6,000
M-	Mucic acid	1,318,320	——
M	Muriaticum	142,653	——
Na	Natrium, or sodium,	581,840	3,000
	Natrum, or soda	781,840	4,000
Ni	Nickel	739,510	3,250
N	Nitricum	77,260	——
Os	Osmium	——	——
O-	Oxalic acid	451,760	4,500
O	Oxygen	100,000	1,000
Pa	Palladium	1,407,500	7,000
P	Phosphorus	392,300	1,500
Pt	Platinum	1,215,230	12,000
Pb	Lead	2,589,000	13,000
P-	Prussic acid	339,560	——
R	Rhodium	1,500,100	5,500
Se	Selinium	495,910	5,000
Si	Silicon, or silicum	296,420	1,000
	Silica	596,420	2,000
Sn	Tin	1,470,580	7,250
Sb	Stibium, or antimony	1,612,900	5,500
Sr	Strontium	1,094,600	5,500
	Strontia	1,294,600	5,600
S-	Saccinic acid	627,850	6,250
S-	Sulphur	201,160	2,000
Ta	Tantalum, or columbium	1,823,150	18,000
T-	Tartaric acid	834,490	8,250
Te	Tellurium	806,450	4,000
Ti	Titanium	——	4,000
U	Uranium	3,146,860	26,000
W	Wolframium, or tungsten	1,207,690	15,750
Y	Yttrium	805,140	4,250
Zn	Zink, or spelter	806,450	4,250
Zr	Zirconium	——	5,000
	Zirconia	——	6,000

The numbers of Berzelius are to be considered as those actually given by xperiment; those of Thomson as corrected numbers, formed by adding or ejecting small differences to make the numbers all multiples of the number of ydrogen, namely 125. The remaining differences between the two series rise either from Berzelius having expressed the number for oxygen which is be radix of the table, one hundred times larger than Dr. Thomson, or from

the latter having always considered the smallest proportion of oxygen found united with another element as a single proportion; whereas Berzelius attends to the properties of the mixed, and if it agrees with those that are known to contain two, three, or more proportions of oxygen, he estimates the proportion of the oxygen accordingly.

As oxygen very frequently unites, on the present system of numbers in the proportion of 1, 1½, 2, 2½, 3, &c. to the other body considered as unity, Dr. Thomson is of opinion that the number taken as that of a single proportion of oxygen is, in fact, twice the real number, and that the usual series is 2, 3, 4, 5, 6, &c. proportions of oxygen, of which a single proportion never enters into combination, but always two at least.

Stahlian Theory.

The proportional numbers remain the same on the Stahlian theory as in the Lavoisierian: only those attributed to hydrogen and oxygen are ascribed to water; and there is considerable reason to suppose that azote or nitrogen is also a very subtle and unweighable element, and that its weight, when separate, or combined with hydrogen and oxygen, is owing to the water combined with it.

The number for water taken from hydrogen gas, as the lightest compound of which it forms the ponderable basis, is 125; but when combined with other ponderable bases it always enters into composition in the proportion of nine charges, atoms or volumes, so that its number is 1,125, or its multiples in the same manner as oxygen, on Dr. Thomson's correction of the usual school hypothesis, generally combines on two proportions at least, or its multiples.

The following are the compounds of which water forms the ponderable base.

Hydrogen gas composed of . .	125	Aq H^{∞}
Oxygen Gas	1,000	Aq $^{8}O^{\infty}$
Azotic gas	1,750	Aq $^{14}N^{\infty}$
Ammoniacal gas	2,125	Aq $^{17}N^{\infty}H^{3\infty}$
Deutoxide of hydrogen . .	2,125	Aq $^{17}O^{\infty}$
Nitrous oxide gas . . .	2,750	Aq $^{22}N^{\infty}O_{\infty}$
Nitrous gas	3,750	Aq $^{30}N^{\infty}O^{2\infty}$
Common air	4,500	2 (Aq $^{14}N^{\infty}$) + Aq $^{8}O^{\infty}$
Dry Nitric acid	6,750	Aq $^{54}N\,O^{5\infty}$
Nitrate of ammonia . . .	9,875	Aq $^{54}N^{\infty}O^{5\infty}$ + Aq $^{17}N^{\infty}H^{3\infty}$

The other numbers remain the same, but the generality of those bodies, esteemed as elementary, are considered as having dry hydrogen combined with them, except chlore and iodine, which must be considered on this theory as containing dry oxygen without water.

Organic substances are compounds of charcoal with water, and the three hypostatical principles.

It is probable that the three elements, hydrogen, oxygen, and nitrogen, existing in a free state, not only in the atmosphere but also in the regions beyond it, produce the phenomena ascribed to light, atmospheric electricity, magnetism of the globe, and the etherial medium. And, that, either free or in combination one with another, or with other elements of the same kind, they produce the phenomena of electrified bodies, galvanism, calorimotion and the like.

AIRS.

VENTILATION OF ROOMS.

A pure atmosphere is necessary to preserve health. There need not any attempt be made to prove it by reasoning; it is a truth universally known and acknowledged.

It has been said that the salubrity and healthy state of the air depend in a great measure on the quantity of oxygen gas it contains. Yet chemists have not been able to detect an appreciable difference between the air of an hospital and that of an open situation. Seguin tried the air of an hospital, the odour of which was disagreeable; but it gave him the same result as the external air. The researches of Priestley, De Mart, Gay Lussac, and others, all tend to establish the same result; which is, that the composition of the atmosphere is essentially the same every where, and that it is a true chemical compound.

If these experiments be correct, they prove that a deadly poison may be infused through the atmosphere, which the art of the chemist cannot detect; but of which we have better evidence than is given by the nicest tests of an analytical chemist, in the pale visages and weakly constitutions of the inhabitants of close and crowded cities; in the unhealthiness of particular districts, and in the important alteration which a change of residence often produces in individuals unaccustomed to such changes.

The atmosphere in the neighbourhood of the sea is said to contain muriatic acid, and no carbonic acid gas. If the presence of foreign ingredients in the atmosphere were attempted to be detected by accurate tests, it is probable that much important information might be obtained.

Men not only change the air by respiration, but discharge a considerable quantity of vapour from their lungs. The experiments on this subject afford results which differ considerably: the experiments of Dr. Hales make it nearly seven grains per minute; Dr. Thomson six grains; Dr. Murray and Mr. Abernethy three grains; Lavoisier and Seguin make it a little more than seven grains per minute. Six grains may be taken as an average result. It will not exceed this; because six grains would saturate eight hundred cubic inches of air at the temperature it is given out in respiration, and it will probably be seldom less.

The mixture of air, azote, carbonic acid gas, and vapour, at the temperature it is thrown off the lungs, being much lighter than common air at the same temperature, it rises with such velocity that it is entirely removed from us before it becomes diffused in the atmosphere.

It appears also that a man gives off, by insensible perspiration, about eighteen grains of vapour per minute; and it has been observed, that air which has been some time in contact with the skin, becomes chiefly carbonic acid gas.

It must, at least, be also desirable to change as much of the air of a room as the moisture given off would saturate in the same time; and, in a room at sixty degrees, on the supposition that, in consequence of the body being chiefly covered, the moisture given off does not, at the utmost, exceed eighteen grains; hence it will be necessary to change three cubic feet of air per minute for each individual that may be in the room: that is to say, as much of the air as the moisture given off would saturate.

And as warmth increases the exhalation of every species of noxious matter; hence, where a higher temperature than ordinary is necessary, a greater proportion of ventilation becomes essential. So that, upon the whole, there should be allowed a change of three cubic feet and a half in every minute for each person; and Mr. Tredgold is of opinion, that, considering the effects of the lamps or candles used for illuminating our apartments, a similar allowance of, at least, one cubic foot of air should be made for each of them.

The power of ventilation in a room should obviously be adapted to the greatest number of people it is supposed to contain at one time. It is obvious that we had better err in excess than defect.

The most difficult season for ventilation is the summer; when the difference of temperature will scarcely exceed ten degrees; hence the ventilation must be adapted to this slight difference of temperature.

Mr. Tredgold, from his theory respecting the draught of air through chimneys and ventilating pipes, is of opinion that if the cubic feet of air that will be vitiated every minute by the number of persons in the rooms, which he thus estimates at four cubic feet for each person, be divided by forty-three times the square root of the height that will be given to the ventilating pipes, the quotient will be the superficial feet that the area of the ventilating openings ought to measure.

This rule must be modified for churches and places of occasional resort, so as to answer to the time, and the number of persons who are to stay in them.

The openings for ventilation should be made in the ceiling, and may be concealed behind some ornament; those for supplying air should be nearly on a level with the floor.

With the means of letting out air at the ceiling, and of letting in a fresh supply at the floor, it is impossible that the ventilation can ever be imperfect, if it be contrived so that winds

may not cause an interruption. On the other hand, when ventilation is attempted by opposite apertures in the sides, it is in windy weather only that ventilation can proceed; and even then not with advantage, as will be evident from the principles established in the fourth chapter. There ought also to be the means of regulating the quantity of ventilation according to the season, by regulating the size of the opening. And it will, in all cases, be adviseable to make the openings for ventilation numerous and small, as this tends to equalize the draught, and prevents those currents of air which are prejudicial to health.

This mode of ventilating rooms, by pipes in the ceiling, cannot be used with open fire-places, unless the pipe from the ceiling is brought down to the fire-place, and there turned up so that the heat of the fire may cause a circulation of air to take place down the pipe into the chimney.

Ventilation of Rooms heated by Close Stoves.

Count Rumford is by no means an advocate for the great ventilation usually thought necessary; he says, although in most of the rooms, in the north of Europe, which are heated by stoves, whose fire-places are not supplied with the air necessary for the combustion of the fuel from the room, the windows and doors are double, and both are closed in the most exact manner possible, by slips of paper pasted over the crevices, or by slips of list or fur; yet when these rooms are tolerably large, and when they are not much crowded by company, nor filled with a great many burning lamps or candles, the air in them is seldom so much injured as to become oppressive or unwholesome; and those who inhabit them show, by their ruddy countenances, as well as by every other sign of perfect health, that they suffer no inconvenience whatever from their closeness.

There is frequently, it is true, an oppressiveness in the air of the room heated by a German stove, of which those not much accustomed to being in these seldom fail to complain, and, indeed, with much reason. But this oppressiveness does not arise from the air of the room being injured by the respiration and perspiration of those who inhabit it. It arises from a very different cause; from a very common fault in the construction of German stoves in general. They are often made of iron; and some part of the stove, in contact with the air of the room, becomes so hot as to burn the dust which lights upon it, which never fails to produce a very disagreeable effect on the air of the room. Even when the stove is constructed of tiles or pottery ware, if any part of it in contact with the air of the room

is suffered to become very hot, which seldom fails to be the case in German stoves constructed on the common principles, nearly the same effects will be found to be produced on the air as when the stove is made of iron.

Though a room be closed in the most perfect manner possible, yet, as the quantity of air injured and rendered unfit for farther use by the respiration of two or three persons in a few hours is very small compared to the immense volume of air which a room of a moderate size contains, and as so much fresh air always enters the room, and so much warm air is driven out of it every time the door is opened, there is much less danger of the air of a room becoming unwholesome for want of ventilation, than has been generally imagined; particularly in cold weather, when all the different causes which conspire to change the air of warmed rooms act with increased power and effect.

Those who have any doubts respecting the very great change of air in ventilation which takes place each time the door of a warm room is opened in cold weather, need only set the door of such a room wide open for a moment, and hold two lighted candles in the door-way, one near the top of the door, and the other near the bottom of it. The violence with which the flame of that above will be driven outwards, and that below inwards, by the two strong currents of air, which, passing in opposite directions, rush in and out of the room at the same time, will be convinced that the change of air which actually takes place, must be very considerable indeed. These currents will be stronger, and, consequently, the change of air greater, in proportion as the difference is greater between the temperatures of the air within the room, and of that without.

People, in general, have great apprehensions of the bad consequences to health of living in rooms in which there is not a continual influx of cold air from without. But the currents of cold air which never fail to be produced in rooms heated by fire-places constructed upon the common principle—those partial heats on one side of the body, and cold blasts on the other, so often felt in English houses—are infinitely more detrimental to health than the supposed closeness of the air in a room warmed more equally, and by a smaller fire.

It has been already shown, that a person changes by respiration, in a day and night, somewhat less than nine pounds, out of the 109 pounds of air that an ordinary room contains, and allowing a night-light to change one-third of that proportion, then a couple of persons sleeping with a light, will only change in eight hours, about 90 cubic feet .02 or 6 avoirdupois pounds .780 of air, and render it unfit for farther respiration; so that but a small proportion only of the air will be rendered unfit for

respiration, in any moderate time, even if the room were closed in the most perfect manner.

Even in respect to the most thorough ventilation, the use of close stoves is advantageous; for rooms are made much more comfortable, and more salubrious, by close stoves; they may be more equally warmed, and more easily kept at any required temperature. All draughts of cold air from the doors and windows towards the fire-place, which are so fatal to delicate constitutions, are completely prevented. In consequence of the air being equally warm all over the room, or in all parts of it, it may be entirely changed with the greatest facility, and the room completely ventilated when this air is become unfit for respiration, merely by throwing open, for a moment, a door opening into some passage from whence fresh air may be had, and the upper part of a window; or by opening the upper part of one window, and the lower part of another. And as the operation of ventilating the room, even when it is done in the most complete manner, will never require the door and window to be open more than one minute, in this short time the wall of the room will not be sensibly cooled, and the fresh air which comes into the room, will, in a very few minutes, be so completely warmed by these walls, that the temperature of the room, though the air in it will be perfectly changed, will be brought to be very nearly the same as it was before the ventilation.

It would be quite impossible to ventilate a room heated by an open fire, in the complete and expeditious manner here described, as the air in a room is partially warmed, or hardly warmed at all, and the walls of the room, remote from the fire, are constantly cold; which must always be the case, where, in consequence of a strong current up the chimney, streams of cold air are continually coming in through all the crevices of the door and windows, and flowing into the fire-place.

Ventilation for Prisons, Ships, Hospitals, and Assembly Rooms.

Sir George Onesiphorus Paul observes, that it is now about twenty years since the deleterious consequences of inattention to ventilation were set forth by Mr. Howard. So strong and so general was the conviction of the public mind, not only as to the evil pointed out, but as regards the remedies proposed by that indefatigable philanthropist, that the legislature thought fit to adopt the whole of his principles, and to make them the basis of several positive laws, under the direction of which the greater number of prisons of the kingdom have been re-constructed, and the remainder, with few exceptions, altered in conformity to the principle recommended by him, namely, that

of introducing currents of fresh air into, and through, every apartment.

In those prisons where attention is also paid to personal cleanliness, the gaol fever is unknown, unless brought into them by prisoners committed in a state of previous infection.

By equal exertion on the like principles, the healthiness of the ships of war has been so improved that they are no longer sources of this desolating pestilence.

Regarding hospitals, it cannot be proved that a relief so complete has been effected. Mr. Howard was not sparing in his strictures on the management of this important branch of our public institutions, but the improvement he suggested, went no farther than simply the introduction of fresh air. The reconciling this advantage with that generally diffused warmth necessary in sick rooms, seems to have escaped his contemplation, yet, considering the importance of pure air to patients, together with the no less important object of securing them from currents of cold air, it cannot be denied that much still remains to be effected.

Parish work-houses, school-rooms for both boys and girls, in every rank of life, manufactories, apartments for public lecturers, and ladies' assembly-rooms, these, together with the circumscribed cottages of the poor, remain in a state most dangerous to health, from imperfect ventilation. To these sources, and to no other, may be traced the few putrid and contagious diseases which occasionally show themselves amongst us, and which, to the credit of free ventilation, can no longer justly be called gaol or ship fever.

At a period of demonstrated success of the doctrines recommended by Mr. Howard, Count Rumford advanced opinions from which important effects have been produced.

In theory, this ingenious person has decidedly negatived the necessity, and questioned the propriety, of ventilation by the admission of currents of air, and in the construction of those buildings most immediately under his direction, he has certainly adopted a practice of a directly opposite tendency.

Opinions of such authority could not fail to be respected, and they must, at least, raise a doubt in the mind of the most confident advocate of an opposite theory.

The county gaol at Gloucester is constructed on Mr. Howard's principles, of admitting air to pass into and through it in two straight lines from one extremity to the other. There is no obstruction to a freedom of current, other than as the streams of air, passing through the long passages open at each end, move with the greater velocity, and of necessity carry with them the weaker currents passing out through the cells at right angles.

From the time this prison was opened in 1791, until the year 1800, about 1300 persons were committed to it, and, on the average, about 100 prisoners were constantly confined in it. In these nine years, the number of deaths were thirteen, and of these four sunk under the effects of disease brought into prison with them. During the year 1800, the prison was crowded in an uncommon and very improper degree, 214 having been confined, and the average number being 167, one prisoner only died, a woman aged sixty. At the opening of the Spring assizes, 1801, the time of the greatest numbers, there was not one prisoner sick, or in the hospital ward.

By this statement it appears that the proportion of deaths is so much below the common average in the ordinary situations of life, that the healthiness of this abode may be said to be peculiar, and it is in proof, that however currents of air may be found injurious to particular constitutions, they are not unfavourable to general health.

Every prisoner in this gaol, when not in the infirmary ward, sleeps in a room containing from fifty-two to fifty-seven feet of superficial space, built with bricks resting on an arch, and arched over so that no air can enter it but through the openings provided for it. As air is constantly passing immediately under and round it, on every side, it is necessarily dry, it is ventilated by opposite openings near the crown of the arch. To that opening which is towards the outward air, there is a shutter, which the occupant may close at will, but is so imperfectly fitted, that when closed, a considerable portion of air must enter by its sides. The opposite opening to the passage, the prisoner has no means of closing in any degree.

During the ten years these rooms have been inhabited, there have been three winters in which the cold has been intense. Yet, notwithstanding the querulous disposition of persons in their situation, a complaint has never been heard, from old or young, male or female, suffering by cold in the night apartments. Fahrenheit's thermometer has never been observed to be below 33 degrees, in the severest night, in the middle region of a cell in which a prisoner was sleeping; whereas, in the ordinary apartments of a dwelling-house, water is frequently known to freeze by a bed-side. And farther, it is the decided opinion of two able physicians, that no ill consequences have arisen from prisoners sleeping in the situation above described.

Hence, therefore, it is a fact established by experience, that in a room containing not more than from 415, or 439 cubic feet of air, in which there is no fire, the body of a person sleeping under a proper allowance of woollen bed-clothes, will so far warm the atmosphere around him, or, to speak more conformable to modern doctrine, so little of heat generated in the body

will be carried off by the surrounding air, that he will not suffer by a current passing at a distance over him, provided the apartment be secured from damp.

The day apartments are in like manner constructed with cross openings near the ceiling or crown of the arch, but there is also in each of them an open fire-place. Respecting these apartments it must be admitted that openings for free ventilation are incompatible with strong fires in open fire-places.

It is certain that in rooms so provided the danger arising from impure air is completely guarded against, yet this advantage is gained at the risk of another evil which, though not so important, should if possible be avoided.

The air which in the same room without an open fire-place would pass inwards by one opening and outwards by the other, being attracted by the fire to supply the constant rarefaction in the chimneys, passes inwards from both openings towards the fire-place, and the body of a person placed near it, being in its current, is exposed to the danger of partial chill. To this circumstance, in these apartments, I am inclined to attribute the few complaints of a dysenterical or aguish tendency which have occasionally interrupted the general health of this prison.

Besides, as the windows are generally closed in the night, although that is the most important time for ventilation, no other change of air takes place but what is effected by the open fires, which, whilst supplied immediately from the middle region, are constantly consuming the best air of the room.

As a remedy to these apparent defects in the ordinary mode of ventilation, Sir George imagined that, as the draft or determination of the air to funnels in the ceilings of the rooms requiring ventilation would be accelerated by the operation of fire, these channels or funnels, so provided, should be rendered air-tight, and brought to terminate immediately under the fire intended to work them. The ash-pit and fire-place should be so closed by doors as to prevent the fire from drawing the air from the room surrounding it: and then the whole draft or consumption occasioned by the fire must be supplied from the further termination of the ventilating channel or funnel.

This funnel may be applied according to circumstances, either to the ceiling of the room in which the fire is made, to the room below, or to that above it, and the draft thus produced may, by a proper apparatus, be increased or diminished at will.

By a fire made in a close stove, a ward beneath it containing about eighteen thousand cubical feet, filled with patients, and which in spite of all former means was ever remarkably offensive, was, in a few minutes, so relieved of contaminated air that the change was sensibly felt by all the patients in it without their perceiving any increased current.

The means of ventilation adopted in this hospital have been applied long ago by Mr. Sutton with perfect facility to ships.

If this stove or grate were properly fitted to this purpose over a lady's drawing-room, on the evening of assembly, it might be set in action, and the room beneath cleared of its impure air without recourse being had to opening of the windows; the openings in the ceiling might be rendered ornamental.

By applying the same principle to German or other closed stoves, the chief objection to their use in crowded rooms would be obviated, and where the indulgence of the habit of open fires was not in question, such stoves, if constructed of earthen materials, would afford a more genial warmth, and a due circulation be at the same time effected.

So fitted and constructed, they would be incontestably better than open fires for the wards of hospitals, poor-houses, manufactories, theatres for lectures, school-rooms, and prisons. Respecting the last-mentioned structures, Sir George observes, that if public kitchens with a sutler were appointed under due regulations, the present necessity for open fires for prisoners to cook individually for themselves would be superseded, much to their advantage.

On the other hand, it must also be observed, that if close stoves acting on this principle were adopted, Count Rumford's objections to the introduction of fresh air would be obviated with regard to any room in which they should be in action, provided the opening through which it entered was made on a level with the ceiling.

Air entering at this level would in the absence of open fires be acted upon by no other draft than the mouth of the funnel in the ceiling, and could not descend in currents to the lower region of the room.

In a room so filled with company as to vitiate the air within it, the atmospheric air entering being specifically heavier would indeed descend and be replaced by the ascending impure air, but as it would not descend by a stronger impulse than its difference of specific weight, it must be slow in its motion, and would produce no sensible current.

SULPHURIC ACIDS.

There are two kinds of sulphuric acids manufactured, as they are used in many processes of the arts.

The first is that obtained by distillation from copperas, which was formerly the most usual process, and the acid was called the *vitriolic acid*, from the name, wiktril, given to copperas by the northern Europeans, and was distinguished into *spirit of*

vitriol, or *oil of vitriol*, according to its degree of concentration.

The second species of sulphuric acid is that formerly obtained by burning sulphur under a glass bell moistened with water, and exposing the sulphurous acid thus obtained to the air until it was changed into sulphuric acid; hence the acid thus obtained was called *oil of sulphur by the bell*, and was sold at a much higher price than that from vitriol. This is now made much cheaper than the other, but as the artisans who formerly used oil, or spirit of vitriol, still ask for the acid by those names, this is sold under those titles.

Sulphuric Acid from Copperas.

The sulphuric acid is produced in great quantities by means of fire, from the common copperas, merely by distillation without any addition. The green vitriol is made use of for this purpose, as it is to be met with at a low price; but Glauber preferred the white vitriol of Goslar, as yielding its acid with less force of fire.

In respect to the operation itself, the following particulars should be attended to:—First, the copperas must be calcined in an iron or earthen vessel till it appears of a yellowish-red colour; by this operation it will lose half its weight. This is done in order to deprive it of the greatest part of the water which it has attracted into its crystals during the crystallization, and which would otherwise in the ensuing distillation greatly weaken the acid. As soon as the calcination is finished, the vitriol is to be put immediately, while it is warm, into a coated earthen retort, which is to be filled two-thirds with it, so that the ingredients may have sufficient room upon being distended by the heat, and thus the bursting of the retort be prevented.

It will be most adviseable to have the retort immediately enclosed in brick-work in a reverberating furnace, and to stop up the neck till the distillation begins, in order to prevent the materials from attracting fresh humidity from the air. At the beginning of the distillation the retort must be opened, and a moderate fire is to be applied to it, in order to expel from the vitriol all that part of the phlegm which does not taste strongly of the acid, and which may be received in an open vessel placed under the retort. But as soon as there appear any acid drops a receiver is to be added, into which has been previously poured a quantity of the acidulous fluid, which has come over in the proportion of half a pound of it to twelve pounds of the calcined vitriol, when the receiver is to be secured with a proper luting.

The fire is now to be raised by little and little to the most

intense degree of heat, and the receiver carefully covered with wet cloths, and in winter time with snow or ice, as the acid rises in the form of a thick white vapour, which, towards the end of the operation, becomes hot, and heats the receiver to a great degree. The fire must be continued at this high pitch for several hours, till no more vapour issues from the retort, nor any drops are seen trickling down its sides.

In the case of a great quantity of vitriol being distilled, M. Bernard has observed it to contain emitting vapours in this manner for the space of ten days. When the vessels are quite cold, the receiver must be opened carefully, so that none of the luting may fall into it. After which, the fluid contained in it is to be poured into a bottle, and the air carefully excluded. The fluid that is thus obtained is the ordinary oil of vitriol, of which Bernard got sixty-four pounds from six hundred weight of vitriol; and, on the other hand, when no water had been previously poured into the receiver, fifty-two pounds only of a dry concrete acid.

Bleyl, a village in Bohemia, possesses among its other manufactures an establishment for the preparation of sulphuric acid. In that manufactory there are two sheds for the distillation of sulphuric acid. One has three galley-furnaces, each containing twenty nine retorts on each side; the other has but two galleys, each of which holds only twenty-one retorts on each side.

Each galley is a long square brick furnace, containing only a grate and an ash-pit, and is composed of two little walls of bricks, which at the top have their surface somewhat inclined inwards.

On each of its two sides is a sort of oven, of the same length as the furnace, and formed by means of a thin brick wall between them and the fire-place. These ovens are intended to dry the vitriol; and they are covered with flags of gneis, forming a kind of step or bank on which the receivers stand.

The calcination of the copperas to whiteness is performed in the ovens which have been already mentioned. The operation is easy. Nothing more is necessary than to put the vitriol into the ovens, and there stir it from time to time. The heat employed in the distillation drives off the water.

The distillation itself is performed in earthen retorts of the shape of a pear, each sixteen inches in length, with the necks but little bent, and having the mouth two and a-half inches in diameter. The receivers for the reception of the acid are also of a similar shape; they are fifteen inches long; their diameter is, at the mouth, an inch and a half, and at the bottom four inches.

The retorts are mounted or set in a galley in pairs, one on one side, the other on the other, and supported by placing the bottom of one against the bottom of the other; their mouths are disposed a little higher than their bottoms, in order that nothing but acid may pass into the receiver. The retorts are coated with luting before being placed in the furnace.

As soon as the galley is furnished with retorts, they are fixed to the walls of the furnace with pieces of brick, and a kneaded mixture of burnt and unburnt potters' earth. A layer of the same kneaded earth is next put upon their necks, and over this another layer of bricks, which fixes the retorts in a firm and solid manner.

When the retorts are thus mounted, long narrow bricks are placed on their ends, in a range the whole length of the furnace. This done, the whole is covered with large thick square bricks, which rest both on the bricks placed endways, and those above the necks of the retorts, which bricks are first coated with a layer of the kneaded earth. These large bricks are cut at the corner to give issue to the smoke. The smoke escapes also by a small chimney at the end of the galley, against the supporting wall.

Into each retort are put three pounds of copperas. When the retorts are filled, the fire is kindled in the furnace, and the phlegm is left to evaporate from the vitriol, which, even after its calcination, still contains a portion of water.

The next thing to be done is to fix the receivers to the retorts, the mouths of which they must enter. They are luted together at the junctions with potter's earth, pulverized and wrought into a paste with water and sulphuric acid. The same luting will also serve to coat the retorts. The hardened luting taken from the retorts and receivers, after the distillation is broken, and with the addition of a portion of fresh earth, wrought again into a soft paste, is applied in a subsequent distillation to the same use as before.

The distillation is commonly finished in the space of thirty-two hours. If the fire were removed sooner there would be a great loss of acid, which would still remain in the ill-burnt vitriol. The fire should be never excessively strong, but always equal till the last six hours, when it is made more intense, that it may expel from the vitriol the last portions of its acid. Each retort affords one pound and a half of oil of vitriol, or half the weight of the dried copperas.

When, after the strongest fire, the pots or receivers are observed to cool, the distillation is then known to be at an end, since the vapours have ceased to communicate heat to them. It is then time to extinguish the fire, and to leave the furnace to cool, that the pots may be removed from it. The furnace

should never be allowed to become quite cold before these be removed, otherwise the residues in the retorts will attract back a part of the acid.

In this manufactory the receivers are emptied only after every third distillation. This management is attended with two advantages; it is a saving of time, and it prevents that waste of the acid which takes place when the retorts are emptied after each distillation; and it causes the acid to be obtained in a more concentrated state; for, every time the receivers are emptied they must be supplied with a portion of water to condense the acid vapours; but when the same quantity of water is used for three distillations instead of one, the acid condensed in it must of course be stronger.

The retorts will serve for three distillations; and to empty them, after each distillation, they are not removed from their places; but the residuums are taken out by means of a small round iron rake, made with a handle of the same metal.

In order to know whether any of the retorts are cracked, they are sounded or struck with another small iron rod or rake; the sound indicates whether they are cracked or not. When any one is cracked, it is taken out, and another, prepared in the same manner as the rest, is put in its place.

Sulphuric Acid from Sulphur.

This acid was formerly thought to be different from that obtained by distilling copperas; and as it was then made by a very troublesome process, it sold at ten pence the ounce, when the acid from copperas was three shillings the pound.

The original process was to put a crucible, filled with sulphur, under a glass bell, moistened on the inside, and by putting a piece of red hot iron on the sulphur to make it burn quick; the moisture of the bell absorbed the sulphurous acid, and this being exposed to the air was changed into the sulphuric, and being thus rendered less volatile, was concentrated by distillation, and thus the oil of sulphur by the bell was made. Moist close weather was chosen for this operation.

Homberg improved this operation so far as to make five ounces in twenty-four hours. He took the largest glass receivers he could procure, and finding the point opposite the centre of the neck by a plummet, he traced, with a writing diamond, a circle of ten inches in diameter, and then applying a red-hot iron ring of the same size to the trace, caused the circular piece to fall out. Under each of the receivers thus prepared, and slung over a pan of water, he put a large earthen pot, filled with ten or twelve pounds of sulphur in a melted state, keeping the vessel constantly full, changing it, if the

sulphur fixed, for another, and removing the crust by an iron wire.

The use of saltpetre in fire-works, causing sulphur and charcoal to burn without the presence of atmospheric air, suggested to Lemery and Lefevre its use to burn sulphur in close vessels. Dr. Ward, the celebrated nostrum-monger, first practised this at a manufactory at Twickenham, and afterwards at Richmond, near London. He used large glass receivers, and put a mixture of sulphur and saltpetre into an iron ladle, supported by a stone-ware pot in the receiver, which was stopped with wooden bungs.

The receivers were placed on their sides, on a sand-bath, gently heated, and had a little water put into them, the vapour of which absorbed the acid: by this means he reduced the price to 2s. 6d. the pound, selling it under the name of oil of vitriol made by the bell.

The use of glass receivers being expensive and inconvenient, Dr. Roebuck began at Birmingham, in 1746, the practice of burning the sulphur, and receiving the product in leaden chambers, or houses, as they are technically called. Since that time, manufactories of sulphuric acid on this principle, have been established, on an extensive scale, in several parts of the kingdom; and the price has been still farther reduced.

It has not yet been settled what dimensions are the best for the leaden chambers. The manufacturers construct them according to their convenience; and Parkes, in his Essays, mentions a manufacturer in Lancashire, who built several rooms 120 by 40 feet, and 20 feet high. [The most modern English chambers are from 12 to 15 feet high, 15 to 20 feet wide, and 80 to 100 feet long; but the exact form or size, seems to have been in every case determined rather by the fancy or whim of the manufacturer, than by any knowledge deduced from actual experiments.] Whatever may be the size of the chambers, the process has been usually conducted in the following manner.

Common brimstone, coarsely ground, is mixed with saltpetre in the proportion of eight pounds of the former to one of the latter; and the mixture is spread on leaden or iron plates, placed one on the other, at a little distance, the upper plate being empty, and on stands of lead within a chamber wholly lined with lead, and covered at the bottom with a thin sheet of water. About one pound of the mixture is allowed to every three hundred cubical feet of atmospheric air contained in each chamber; and when a charge in this proportion has been placed in one of them, the mixture is lighted by means of a hot iron, and the door is closed.

The combustion of the two substances, if well mixed, continues about forty minutes. In about three hours the gas is all

condensed, and the chamber is thrown open, for a quarter or half an hour, to admit atmospheric air, and prepare it for another burning. The plates are again charged, and the same process is repeated every four hours, without intermission, either by day or night, until the water at the bottom of the chamber is thought to be sufficiently acidified. This is judged of by the acid turning black, when it is drawn off by means of a syphon, into a leaden cistern.*

The acid, which has then the specific gravity of about 1.450, is concentrated by the action of heat in leaden kettles, until it has acquired such a specific gravity as best suits the manufacturer's purpose. It is afterwards boiled in very large glass retorts, set in sand-pots, till all the sulphurous and nitric acids are driven off, and it is fit for the market. Of late years these retorts have had coils of platinum wire, or strips of platinum foil put in them, to equalize the boil, and prevent those concussions which were apt to crack the retorts. The necessity for the concentration by means of heat, arises from the water, after it has taken up a certain quantity, refusing to absorb the acid so readily as at first. Care too must be taken, when the acid is in the leaden boiler, that it be not too much concentrated, for the boiling point of concentrated acid, and the melting point of lead, are so near to each other, that the leaden boiler may be destroyed.

Some manufacturers remove it at once into the glass retorts, and do not steam it in lead, which prevents the acid combining with so large a quantity of this metal. The acid is usually left in the retorts for twenty-four hours, when the retorts are either hoisted out of the sand, and the acid poured into carboys, or the acid is drawn off by a syphon, without moving them.

Lately, platinum bodies, placed within pots of cast-iron, of a corresponding shape and capacity, have been substituted for the glass retorts, and have been found to save fuel, and quicken the process of concentration. Parkes mentions that he had a platinum still constructed for rectifying sulphuric acid some years ago: it cost him three hundred pounds, but answered the purpose perfectly well.

The oil of vitriol thus prepared, always contains sulphate of potash, derived from the nitre, and sulphate of lead, derived from the leaden vessels used in the process.

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* This is a very uncertain criterion for judging of the strength of the acid in the chamber, as it depends not merely on the state of the concentration of the acid, but on the cleanliness of the chamber or freedom from vegetable matters which are charred by the acid when it acquires a certain specific gravity. Other things equal the amount of discoloration will be determined by the quantity of these impurities.—Am. Ed.

In order that this method should succeed, it is essential that air be present to maintain the combustion, that the closed chamber do not allow the volatile matter which arises to escape, and that water be present to absorb it. For a long time, however, the theory of this method was involved in doubt and obscurity.

It was found that one hundred parts of nitre, containing only thirty-nine and a half of oxygen, when combined with the requisite quantity of sulphur, produced a quantity of sulphuric acid, containing twelve hundred parts of oxygen. Besides, after the combustion of the sulphur, the residuary salts contain nearly as much oxygen as was originally contained in the nitre; and twelve hundred parts of oxygen in the acid could not be accounted for.

Pluvinet first attempted to explain this circumstance, in a letter to the elder Chaptal, and since then, Messrs. Clement and Desormes, two French manufacturing chemists, have revived, after a lapse of some years, this theory, and their explanation has since been received as true, by Mr. Dalton and Sir H. Davy. It is now supposed, that the burning sulphur, taking from the nitre a portion of its oxygen, forms sulphuric acid, which, uniting with the base of the nitre, or potasse, displaces nitric and nitrous acids in vapour, which is decomposed by the sulphurous gas, into nitrous gas, or deutoxide of azote. Being naturally only a little heavier than air, and being then rarefied by the heat, the nitrous gas rises to the roof of the chamber, and there coming into contact with atmospheric air, by means of a hole left there for that purpose, and without which, as they affirm, the manufacturers found that the acidification would not go on, forms nitrous acid vapour, which being a heavy body, immediately precipitates on the sulphurous flames. Sulphuric acid and nitrous gas are again formed, and the latter again mounts for a new charge of oxygen, again to re-descend and transfer it to the sulphur.

Sir H. Davy has, however, since shown, that water is necessary to the mutual action of sulphurous gas and nitrous gas, and unless this fluid is present the process does not go on. With this additional fact it would appear, that a small volume of nitrous acid vapour, by its alternate and frequent changes into oxide and acid, is capable of acidifying a great quantity of sulphur.

A manufacturer of this acid remarks, in the "Chemist," that the method described by Parkes has been abandoned by the English makers. It proves, however, though Messrs. Clement and Desormes affirm the contrary, that the acidification will go on without any hole, for the admission of atmospheric air, in the roof of the chamber. In the old method of opera-

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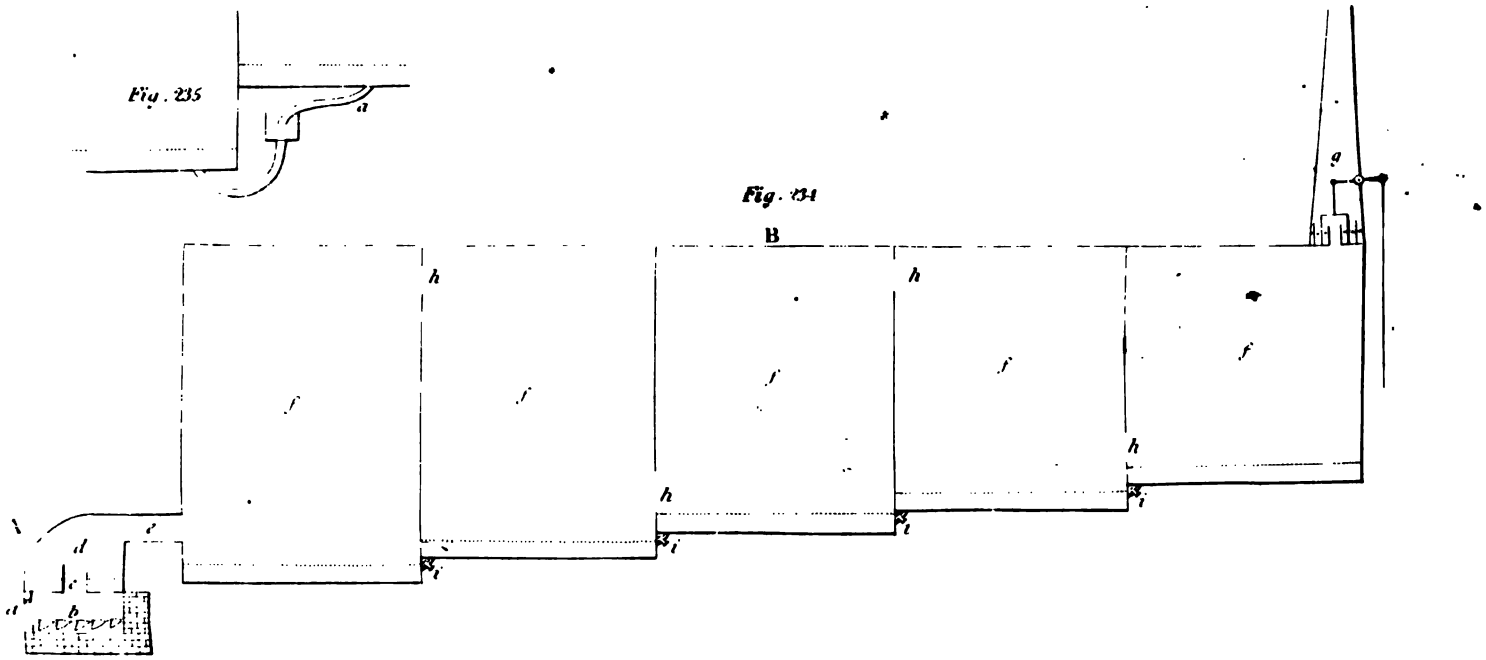
Fig. 235

Fig. 234



ting, the first charge, by being burnt, would form some portion of incondensible gas; this, by the admission of atmospheric air at the doors, was driven to the top, and thus each charge lessened the capacity of the chamber, until, after a week's work, the sulphur would scarcely inflame. On a moderate computation, not one half of the sulphur was really used. The maker, of course, could never have made sulphuric acid by this method, at the price it was usually sold at, but that the unconsumed sulphur, mixed with the sulphate of potash, was sold to the maker of roll sulphur, at a price nearly that of duty-paid sulphur, nine-tenths of which duty the sulphuric acid maker had returned to him, by his disregarding his oath, that the said sulphur was all consumed by him, in the making of oil of vitriol.

[The foregoing is a correct description of the method of conducting this branch of manufacture still practised in many of the old works in England, and almost universally in those of the United States. In recently constructed works, the process is conducted on a much improved plan; that of keeping up a constant combustion and circulation through the chamber from the commencement to the end of the process. Fig. 234, will serve to illustrate this plan, though the division of the leaden chamber, *b*, into compartments at different elevations from the earth, relates to another plan engrafted upon this, to be afterwards described. For the present, we will consider the chamber, *b*, as a plain one on the ordinary construction. *A*, is the fire-place in which the sulphur and nitre is burned, surmounted by a small leaden apparatus containing water, which is boiled by the heat produced by the combustion of the sulphur: *b* is the fire-place which is built of brick; *a* the door leading to the fire-place; *d* the leaden vessel placed directly over the fire-place, the bottom of which is covered with water to the dotted line; *c* a circular opening six inches in diameter, through which the sulphurous vapour ascends from the burning sulphur; and *e* the passage leading into the chamber: at the opposite extremity of the chamber is a wooden chimney, or flue, *g*, for the escape of the incondensible vapour of the chamber, which is ordinarily kept open, but which may be closed or lessened at pleasure, if the escape of sulphurous acid is apprehended, by the common water trap or water valve.

Now, the operation of this apparatus is this:—the sulphurous and nitrous gases produced by the combustion of the materials in the fire-place, *b*, ascend through the tubular aperture, *c*, into the small chamber, *d*, where they meet and mix with a portion of watery vapour, which arises from the water in this vessel (which is kept in a state of gentle ebullition by the combustion of the sulphur underneath) and pass together into the chamber, *B*, where the changes already described agreeably to the views

of Messrs. Clement and Desormes and Sir H. Davy take place; a portion of undecomposed air, also passes into the chamber to supply the waste of oxygen, and the incondensible nitrogen, and perhaps small portions of other gases, pass off through the chimney, *g*; in consequence of this constant change in the aerial contents of the chamber, the process may be carried on without a moment's interruption till the water in the chamber is impregnated to the required point.

The theory of Messrs. Clement and Desormes does not essentially rest, as the author and others would seem to infer, on the question whether this process can be profitably carried on with or without an opening in the top of the chamber where all other openings are closed. It is certain that the combustion of the sulphur with the nitre may be effected to a certain extent without any opening at the top of the chamber, or in any part of the chamber, but it is equally certain that it may be supported a much longer time where there is an opening for the admission of air. If the combustion be attempted in a chamber completely enclosed, it is limited by the absorption of the oxygen of its own atmosphere; if in a chamber with a small opening at top only for the admission of air, it is limited and interrupted in a short time by the accumulation of incondensible gases, which occupy the whole of the chamber, and in that way prevent the admission of oxygen. Hence the necessity on the old plan of making oil of vitriol, of so often stopping the process of combustion, and throwing open the chamber for a thorough ventilation, or sweetening, as the workmen called it. It would seem a little remarkable that these accurate observers had not been conducted by their researches on this subject to one of the most signal improvements in this branch of manufacture. They seem to have been so much occupied with the beautiful play of chemical attractions between the gaseous products of the combustion and the oxygen of the atmosphere as to have overlooked the necessity of vent for the incondensible nitrogen. The admission of air through the top of the chamber only, does not necessarily follow from the theory of these gentlemen; but they probably apprehended, as many practical oil of vitriol-makers of the old school still do, that, if a vent were also made at the fire-place, and a current established in the chamber, there must be great danger of loss of considerable portions of the sulphurous and nitrous gases at the upper aperture. But the most ample experience has demonstrated that no such loss need be feared where the process is conducted with ordinary caution. So far is this from being the case, that the writer recollects visiting a very large establishment in Ireland, conducted on the principle of a constant combustion, in which several chambers were completely enclosed, and covered by a large building, with a tight roof, into which the incondensible

gases were suffered to escape without any other ventilation of the building than the ordinary doors; and yet the atmosphere was far less offensive from sulphurous fumes than such buildings usually are with chambers constructed on the old plan.

When the water in the leaden vessel *d*, becomes saturated with sulphuric acid, it may be drawn off and its place supplied by a fresh portion: it will, indeed, be necessary to introduce fresh water frequently, to supply the waste from evaporation; but it will seldom be required to draw off the liquid, as the absorption of acid will be very slow at the boiling temperature of the water. It would be well to insert one or two gauge cocks; similar to those used in steam boilers, only of lead, into this small chamber, to enable the workmen to regulate the admission of water; or what would be equally simple, and, on the whole, preferable, a glass tube half inch in diameter, twice bent at right angles, one end of which should enter above, and the other below the water line, by which the attendant could at all times know the exact amount of water within.

In order to moderate the combustion, it is now, I believe, the invariable practice of oil of vitriol manufacturers to mix the sulphur and nitre with pipe clay; for this purpose, for every 100 pounds of brimstone, they take fourteen pounds of pipe clay, and fourteen pounds of crude nitre; the latter is dissolved in as little water as possible, and then added to the clay and sulphur, which are previously pulverised, and the whole beat into a stiff paste; this paste is then moulded into lumps of a conical form of twenty pounds each, and when nearly dry, they are placed in two or three rows in the furnace, with the apex of one touching the base of the other; the object of this particular form and arrangement of the lumps is to secure the combustion of the lumps in succession; as they touch only by a small surface, the combustion of the first in order is nearly completed before the following one is kindled. It is usual to mix the materials the day before their use; the lumps should be damp, but not wet. The proper degree of moisture will, however, be soon learned by trial. The lumps retain their form after the combustion has ceased, and will be found to consist of sulphate of potash and sulphate of alumine, with a considerable excess of base. They are used in the manufacture of alum.

With regard to the density of the liquor when drawn from the chamber, that will depend much upon the choice of the operator; at least the writer is not aware of any accurate experiments having been instituted to determine the most economical points at which to stop the process. Some manufacturers draw off the acid at a specific gravity of 1.250, and others not till it reaches as high as 1.500. The nearer the liquor approaches the saturated point, the slower will be the absorption; but, on the other

hand, the denser it is when drawn from the chamber, the less fuel and time will be required for its subsequent concentration. The practice of the manufacturer may, therefore, be modified by circumstances to a considerable extent; if his fuel is cheap, and his chambers limited, it will be adviseable to draw off the acid from the chamber at a low specific gravity; on the contrary, if fuel be dear, and his capital for investment in chambers ample, it may be profitable to carry the concentration in the chamber much higher.

Theoretically one hundred pounds of sulphur with the above quantity of nitre should yield three hundred and twelve pounds of concentrated sulphuric acid; but two hundred and eighty pounds is accounted a good product in practice. It is not contended that the yield of acid is greater in the new plan of operating by a constant combustion; but only that there is a great saving of labour and time in conducting the process, and that more acid is produced from a chamber of a given capacity,—considerations of no ordinary weight in a branch of manufacture requiring under the most favourable circumstances so heavy an outlay of capital as this.]

In the present plan pursued by the English manufacturers, the sulphur and saltpetre are in different vessels, and both are in furnaces separate from the chamber, and several feet distant; consequently, all the advantages of the new French method, hereafter described, are obtained with this additional one, that sixteen charges can be burned in twenty-four hours.*

It has long been an object with the manufacturers to procure sulphuric acid without the assistance of saltpetre; and this has been performed in England by Messrs. Hill and Huddock, who have taken out a patent for this purpose. They subject pyrites, or sulphuret of iron, in a state of powder, to a strong red heat, in cast-iron cylinders, communicating with a chamber lined with lead containing water, into which, they say, they inject steam and a certain imponderable substance. As this substance is not mentioned; their patent is, of course, of no force. It seems probable that they use common manganese, or the black oxide of that metal, instead of saltpetre, either mixed with the pyrites, or in a separate cast-iron cylinder.

It is found that the sulphur evolved by this means, and burning, produces sulphuric acid, which is immediately condensed in the water. The great advantages of this method are, that

* What is intended here by putting the nitre and sulphur in separate vessels it is difficult to conceive; certainly no manufacturer ever thought of burning the nitre and sulphur in separate vessels: crude notions of this description in relation to the chemical arts not unfrequently find their way into our scientific periodicals and thence into our best systematic works through inadvertence.—Am. Ed.

no saltpetre is necessary, and pyrites, a material which was before hardly put to any use, but that of making copperas, is the material employed for furnishing the acid.*

The improvements in the manufacture have been so great in England, that a pound of acid, which twenty years ago cost sevenpence, may now be had at the wholesale price for less than twopence.

The quantity consumed in Great Britain is about three thousand tons a year.

French Manufacture of Oil of Vitriol.

The principles of the French method of manufacturing this acid were the same as those of the method followed in England; but the details very different. Mons. Payen informs us that sulphuric acid was manufactured in France, forty years ago, by burning sulphur with saltpetre, but at present, by reverting to the old process of burning sulphur alone.

The process with saltpetre consisted in shoving into a chamber lined with lead, containing from five to ten thousand cubic feet, an iron carriage, carrying a cast-iron dish full of burning sulphur, the combustion of which was promoted by a portion of saltpetre, amounting to ten, fifteen, or even twenty in the hundred. Some manufacturers injected a shower of water by a forcing pump, through a rose. When it was supposed that the combustion was completed, and that the acid formed had been condensed by the water, the door was opened at which the chariot had been introduced, it was taken out to clear away the residuum, again loaded, and the operation repeated.

The acid obtained was evaporated and concentrated in leaden boilers 50° to Baumé, and then concentrated in glass retorts, ranged, as many as twenty or thirty, in a sand bath, and all heated by the same fire.

The result of all these proceedings was to obtain from 150 to 200 parts of sulphuric acid, of the specific gravity of 1,845, or 66° of Baumé for every hundred of sulphur employed, and very often the operation entirely failed. The residuum was at first flung away, although it contained nearly one-third of the sulphur used, and much sulphate of potasse; but afterwards it was sold to the alum-works, and used in that manufactory.

The putting in the sulphur by a carriage was then done away, and an immoveable furnace constructed under the chamber.

* The writer was informed, when in England in 1827, that the plan of Messrs. Hill and Huddock had not answered the expectations first formed of it, and that the manufacture on these principles had been abandoned. A similar attempt to manufacture this acid from pyrites was made a few years since, by a manufacturer in Manchester, but did not succeed well. The ruins of an expensive apparatus remain to attest both the enterprise and misfortunes of the projector. Am. Ed.

The dish in which the sulphur was burnt was heated by fire, and the mixture of one hundred parts sulphur to ten or twelve saltpetre was introduced from time to time, by means of a small door for this purpose. A hole, two inches above the level of the sulphur, permitted a constant ingress of air, and a chimney at the other extremity created a draught which carried off the unconsumed gases. In damp weather, particularly, they fell all around, and destroyed all vegetation in a pretty extensive circle.

Some acid was always left in the chamber; and as more was formed, a quantity was drawn off and concentrated in glass vessels. This method of concentrating the acid is still generally employed, except that, instead of several glass retorts, a single platinum alembic is now in use. By this process from 250 to 260 pounds of acid, of the specific gravity of 1·845, are obtained from one hundred pounds of sulphur.

The following method, which is practised by some manufacturers, is said to give constantly three hundred pounds of acid of the specific gravity of 1·845 for every one hundred pounds of sulphur. According to the theoretical calculation of the proportional charges of sulphur 100, oxygen 150, water 62·50, the sum would be 312·50, and it is scarcely possible to come nearer on a large scale.

According to this new method, the best size for the chambers is thought to be about fifty feet in length, twenty-seven in breadth, and fifteen in height, or rooms containing about twenty thousand cubic feet; chambers of different dimensions may be used; but this is the size to which the manufacturers give the preference.

Fig. 103, represents a chamber of this kind. A leaden cylinder, *b*, eight feet in diameter and six feet in height, enters the chamber at one end, and rises about ten inches above the floor, *c*. The cylinder at its lower part, *d*, turns inwards and upwards, and forms a gutter, *e*, concentric to the cylinder, in which there is a constant quantity of acid kept as high as *g*, to prevent the lead from getting too much heated, and to profit by the heat of the acid which continually passes. The whole is placed on a mass of brick-work, *h*; in the middle of which there is an iron dish, *k*, three feet four inches in diameter, and one inch thick, slightly concave, and having a rim three inches high. This is set above the fire, *b*, which ought to heat all its under surface. Level with the rims, a door, *m*, is made into the leaden cylinder, two feet high, eighteen inches wide, and having at its lower part a hole, *n*, an inch in diameter.

At the other end of the chamber are two ventilating valves, *p*, and two wooden pipes, *q*, sufficiently high to promote a strong draught.

Every thing being ready, the door and the valves closed, and the bottom of the chamber covered with diluted sulphuric acid, at 10 or 15° of Baumé, the fire is lighted under the iron dish, and when it is so hot that a handful of sulphur thrown on it instantly takes fire, it is charged with sulphur, of which it takes fifty kilogrammes, about 115 pounds, for every operation.

At the same time, a retort containing nine pounds three-quar-

ters of nitric acid, and one pound four ounces of molasses, is heated. The nitrous gas disengaged in this process is conducted by a pipe into the leaden cylinder, two feet above the burning sulphur, and this operation is continued till all the nitrous gas is disengaged. What remains in the retort after this operation is crystallized, and makes oxalic acid, so that the nitrous gas is thus procured without any expense, as a secondary product, and the expense of saltpetre totally avoided.

About two hours after beginning to burn the sulphur, the cock of a boiler, *s*, is opened, the steam-pipe of which, *t*, enters the middle of the chamber. Its diameter is one inch, which, at its mouth, is reduced to half an inch, in order that the vapour, arising from the boiling water in *s*, may issue with some force. This cock is to be kept open till all the vapour necessary for the absorption of the acid, which is about the produce of fourteen gallons of water, has been thrown into the chamber. Soon after the introduction of the vapour a condensation in the interior is perceptible, and the hole, *n*, is opened in order to give access to the atmospheric air.

In general, the injection of vapour is stopped about an hour after the combustion of the sulphur; and when this is done, and it is supposed that the condensation is complete, the door of the cylinder, and the two valves for ventilation, are opened, in order to renew the air of the chamber, and another operation is then begun. This may be repeated four times in twenty-four hours; but it is difficult to keep up this constant work. It is better to perform only three, and even as two require less close inspection, and the apparatus is less liable to accidents; and more produce in proportion being obtained, it is, perhaps, on the whole, better to work it only twice in the twenty-four hours, namely, in the day time. The metal suffers considerably less from its alternate expansion and contracting under this mode of operating.

The bottom of the chamber should always be covered with liquid; and as it is laid inclined to the horizon, the liquid is nearly nine inches deep at one end, and only one inch and a half at the other; the overplus only of acid should be drawn off daily. The concentration can be carried on in the chamber to a considerable extent, even to 50° or more of Baumé; but then the acid absorbs a portion of the nitrous gas, from which it is scarcely possible afterwards to free it. In consequence of the water necessary for the acid being furnished from vapour, and thus being, in fact, distilled water, the acid obtained is not contaminated with the sulphate of lime, usually contained in common water, and it dissolves indigo without injuring its beautiful blue colour.

If it is ever found necessary to draw off the whole of the acid from the chamber, for making repairs, or from any other cause, care must be taken to cover the bottom of the chamber, before beginning anew, with weak acid. Some manufacturers, who have neglected this precaution, and put either plain water,

or nothing into the chamber, have obtained no product. Heat and water are essential to the formation of the acid; and it has been observed, when working four times in the twenty-four hours, or constantly, that in dry weather, particularly if frosty, the acid was never condensed. As the cause of this circumstance was not known, it was attributed to the chambers, which were said to be sick, and would not work. The remedy was to throw steam into the chamber, and thus heat the sides. The same precaution must be taken, if the chamber is begun to be used in dry or cold weather.

The acid thus obtained is first boiled down in shallow leaden pans, about a foot deep, in which it is brought to fifty degrees of Baumé. After this it is distilled in a platinum still, having a moor's head of the same metal, and a leaden adapter. The water which comes over brings with it some acid, and hence may be advantageously used in addition to the liquid in the chamber.

The concentrated acid is drawn out of the platinum body by the help of a platinum cane, which is surrounded by a copper pipe, through which a current of cold water is made to run, in order to cool the acid, and prevent it from cracking the stone-ware cisterns in which it is first kept by the manufacturers. From these cisterns it is drawn off into stone-ware bottles, with stoppers of the same material, luted over with clay.

No accurate estimate of the quantity of acid obtained in England from the combustion of sulphur has been published, to enable us to compare accurately the vlaue of the two methods. If, however, the French statement we have given is correct, we should suppose the latter the most profitable, as the expense of the saltpetre is entirely avoided, there being a sufficient demand for the oxalic acid.

The only drawback seems to be the recommendation not to repeat the operation more than three times in the twenty-four hours, while, by the English method, the work is constantly going on. This is a point of great importance in consequence of the large capital embarked in such manufactories; but it must, at the same time, be remarked, that there is no reason why the English method should not cause as much injury to the buildings and machinery as the French.

Independent of this, the latter seems to have considerable advantages. The substituting a plate of sulphur, exposed to exterior heat, and the mixing the nitrous gas with the flame of the sulphur, instead of mixing the two raw materials together, and the method of throwing in steam to supply both heat and pure water, must unquestionably produce a greater quantity of acid than is obtained by the English method, and of a purer nature. Whether this advantage is sufficiently great to counterbalance

the expense of the fuel consumed, we have no means of determining, but we have the testimony of the French manufacturer in its favour.

[There is reason for believing that no extensive work for the manufacture of oil of vitriol has ever been conducted on the principle described in the foregoing paragraphs, not even in France. The writer visited several establishments of this kind in Paris and Rouen, in 1826. They were all conducted on the old English plan of close combustion of nitre and sulphur, with the modern improvement only of a separate chamber for the combustion; but in this part of the process, the materials were kindled on the old plan of a separate fire underneath a large iron basin, in which the sulphur and nitre were placed. In one instance only, did he witness the arrangement for injecting steam into a chamber, in the manner described by the author, and in that case the boiler had evidently not been used for a length of time, although the chamber was in constant operation; he either did not inquire, or does not now recollect, the reason assigned by the manufacturer (M. Chorrillon) for the disuse of this apparatus. An English chemical manufacturer of great experience, combined with much scientific knowledge, informed the writer that he once came very near paying dearly for this suggestion of a theoretical chemist, in the destruction of his chamber: notwithstanding the valves provided to open both inwards and outwards, he found the contractions and expansions of the aerial contents of the chamber so sudden and violent, as to render it impossible to proceed with the process. Another experienced manufacturer informed him, that he tried the effect of steam in a small chamber, erected for this purpose, and could form no vitriol whatever. The advantage of steam in any considerable quantity is indeed very problematical, in this process, independent of the mechanical objections to its use. With regard to the use of nitrous gas, from the action of nitric acid on molasses, instead of nitre as mentioned by the author, there seems no objection to the measure in theory; but it probably remains to be demonstrated how far it is practicable, and profitable on a large scale. The account given of this method of manufacture is the substance of an article in the Dictionnaire Technologique, which has never been much esteemed by practical manufacturers.

Dr. Hempel's Oil of Vitriol Chamber.

Various attempts have been made to increase the absorption of the sulphurous vapour, by dividing and subdividing the interior of the leaden chamber, or with the view either of bringing the sulphurous acid more frequently in contact with the water of the chamber, or of presenting to it different portions of water, in different states of saturation. One of the most systematic arrange-

ments of this kind, is that of Dr. Hempel, a celebrated chemical manufacturer of oil of vitriol, and other chemical articles, of Berlin, the particulars of which were given me by an English chemist. Fig. 234, exhibits a vertical section of Dr. Hempel's chamber. It is 100 feet long, 17 feet wide, and divided into five different compartments by transverse partitions. The deepest of these compartments is 15 feet, which is that nearest to the furnace in which the sulphur is burned; each succeeding one is one foot less in depth, and, consequently, the last is only 10 feet high. The position and depth of the water in these compartments is represented by the dotted lines. *i i i i* Represent tubes and stopcocks which must be of lead or glass, through which the liquor may be drawn at pleasure from the higher chambers to the lower. The first partition is pierced near the top of the chamber by a row of circular apertures, near the top of the chamber, and extending from one side of the chamber to the other. The second is pierced with a similar row of apertures near the surface of the fluid, in the third compartment: the third partition is pierced like the first at the top, and the fourth, like the second at the bottom. In the sketch the position of these apertures are represented as though the partition were actually terminated, or cut off in that line. The sulphurous and nitrous fumes enter the first compartment through the pipe, *e*, along with a portion of air; the ordinary changes here take place, and a portion of sulphuric acid is formed, and absorbed by the water of this compartment, the remaining gases then rise, pass through the apertures at *h*, (which may be 10. in number, of two to three inches in diameter,) into the second compartment, where the same changes as in the first occur, and so on through the remaining three, the current setting through them in the direction and course of *h h h h* and finally out at the chimney, *g*, in which the water valve at the base should have been represented open. By this arrangement, an active circulation and mixture of the aerial contents of the chamber are secured, and the gases either at their entrance, or escape from one apartment to another, are made to sweep over, and in immediate contact with the surface of the water.

It is obvious from the sketch, that the water in the first compartment will be soonest saturated, because there the sulphurous and nitrous vapours will exist in the greatest degree of concentration, and so on each chamber successively will be weaker and weaker to the last. When, therefore, the water in the first compartment is saturated to the required point, it is drawn off; (for which purpose it is convenient to have the leaden chambers elevated above the leaden evaporating pans:) there the liquid in the second compartment is drawn into the first, that of the third into the second, and so on till the last compartment is empty,

which is then replenished with fresh water, and the process of combustion again renewed and continued till the water in the first compartment has become saturated as before, when the operations of drawing off and changing the liquid are repeated.

By this arrangement of the chamber two important objects are secured: first, the exposure of that portion of the liquid which is nearest the point of saturation, and which in consequence absorbs the gases with the greatest difficulty, to the sulphurous and nitrous vapours, where they exist in the most concentrated state; and, secondly, the ensuring a complete absorption of the sulphurous fumes, by exposing them, before they leave the chamber, to a portion of fresh, or but slightly impregnated, water. The same principles apply, of course, to the intermediate compartments.

Such is Dr. Hempel's chamber: there can be little doubt but some arrangement of the kind may be made to increase the rapidity of absorption; but it may be a question whether the advantage would be such as to indemnify the manufacturer for the additional expense and the greater liability to derangements of so complicated an apparatus as the one just described. Various simplifications will occur to the practical chemist on a moment's reflection, which may still embrace its leading principles. Manufacturers of oil of vitriol, who happen to have two or more chambers contiguous or near each other, but upon different levels, may avail themselves of them by forming communications between them with a flue, for ventilation at the extreme of one chamber of the series, and a furnace at the other. Such an arrangement, indeed, the writer is well informed, has actually been made in an extensive oil of vitriol work in Liverpool, and with satisfaction to the proprietor. The change from the common plan to the new, including the substitution of the new method of constant combustion, for the old would be attended with a very trifling expense. Many chambers, indeed, would require no alteration whatever; for they are now very generally provided with chimneys or flues for occasional ventilation, and the fire-place, which is now usually situated without the chamber, need only be left open in the first chamber in the series, and closed in the others.

The arrangement for boiling water over the fire-place, as represented at A, in fig. 234, and already described, is not peculiar to Dr. Hempel's chamber. It is the invention of a Swiss manufacturer, and has not before been made public. It is a very simple and effectual method of introducing steam into the chamber; and as the amount of evaporation must depend directly upon the rapidity of the combustion and the quantity of sulphurous and nitrous gases produced, by varying the size of the pan over the fire-place, the quantity of steam may be regulated to any mea-

sure, and will always bear the same proportion to the sulphurous fumes. But the utility of the arrangement depends on the general question, not yet settled, how far steam, under any circumstances, is favourable to the formation of sulphuric acid from the sulphurous and nitrous gases over water.

Fig. 235 shows a simpler method of drawing the liquid from one compartment to another of a chamber on Dr. Hempel's plan, than the one represented at *i i i i*, in fig. 234, and less liable to fall out of repair; the patulous extremity of the lower tube is above the surface of the liquid in the lowest compartment. When the liquor is drawn from the upper chamber, and a fresh portion is to be introduced, the leaden tube, *a*, need only be bent so as to bring its outer extremity above the level of the liquid within the chamber, and all is secure. The furnace, or fire-place, A, in all its dimensions, and the height of the chamber, B, of fig. 234, is drawn to a scale of eight feet to an inch; but the length of the chamber to a scale of sixteen feet to an inch, to accommodate the plate.]

In case of the sulphuric acid being rendered impure by any accidental circumstance, the best method of divesting it of its impurity is by a fresh distillation. This is generally performed in a glass retort. It must be observed, however, that if green glass is employed the retort is apt to crack in the middle of the process; even flint glass retorts will crack if the sand rise round them higher than the evaporable charge. Hence a capella vacua is preferable to the ordinary sand-bath.

The watery fluid which first distils over on this occasion may be received in a separate vessel, and another fitted on the instant a strong acid begins to come over. By this means the acid is procured in its pure state, and such it is required to be for accurate and exact chemical experiments.

There is another way proposed by some, which, however, is very defective, of purifying a dark-coloured oil of vitriol.—This consists in merely boiling it up in a glass retort, and suffering it afterwards to grow cold, and to clear itself slowly and by degrees.

The acid becomes colourless and limpid like water; but it may nevertheless contain various extraneous particles, which cannot by this means be separated from it. Upon a similar decomposition of the combustible matter is founded, also, the following method of purification; viz. from half an ounce to six drams of nitre are mixed with one pound of dark-coloured oil of vitriol, and the mixture is heated to the boiling point, or till the dark colour disappears. In each of the latter cases the sulphuric acid is at the same time rendered impure in another way.

On rectifying the oil of vitriol, as well as in the second purification of it, there is found an earthy saline sediment, which is more or less abundant, in proportion to the impurity of the oil. In the Nord-hausen, and other similar oils of vitriol, which are produced by the distillation of vitriol, this kind of impurity is usually very trifling; but in the English oil of vitriol it is very considerable, on account of the acid being prepared with-

out distillation; and, indeed, in the way in which that is prepared it is possible for contaminations of various kinds to take place, particularly of sulphate of potasse and sulphate of lead.

Berzelius has found traces of titanium in English oil of vitriol, and of selenium in the Swedish.

For the purpose of analysis, it will be convenient to keep not only the concentrated acid, but also some of the specific gravity of 1,135, as one dram measure of this will saturate two dram measures of potasse water at 1,100; two of soda water at 1,070; one of ammonia water, at 0,970; one of sub-carbonate of potasse water, at 1,248; two of sub-carbonate of soda water, at 1,110; and two of sub-carbonate of ammonia water, at 1,046.

Uses of Sulphuric Acid.

This acid is extensively used in the chemical arts, particularly in bleaching, and some of the processes of dyeing. It is also used to separate the acids of nitre and common salts from their bases, and on numerous other occasions. In medicine a few drops are exhibited as a tonic, and it is by some used as a caustic to fresh wounds.

The composition of the strongest oil of vitriol, specific gravity 1,847, is supposed to be one atom of sulphur with three of oxygen and one of water, being the sulphas hydricus of Berzelius, S:·+HH·, that chemist supposing the water acts as a base. The anhydrous or dry acid, acidum sulphuricum of Berzelius, is S:·; but according to Dulong's opinion this last is not an acid, but merely the basis, which is converted into the sulphuric acid by decomposing water, so that the composition of the sulphuric acid is really S:: H, as Dulong esteems water as H· only.

On the Stahlian theory sulphur is S H, and oil of vitriol S O + 33 Aq.; the glacial or icy oil, or anhydrous acid being S O + 24 Aq.

According to Mr. Dalton and Dr. Thomson, the specific gravity of the acid combined with water is as follows: one proportion or atom of acid, with

1	of water -	1,850
2	- -	1,780
3	- -	1,650
10	- -	1,300
15	- -	1,220
17	- -	1,200
38	- -	1,100

Dr. Percival, Trans. Roy. Ir. Acad. found that by dissolving two Troy ounces of sulphate of potasse in nine ounce measures of oil of vitriol, at 1,845, the specific gravity was raised to 1,892; so that the specific gravity is not to be trusted as a test of the strength of the acid; but recourse must be had to the saturation of carbonate of soda.

Some manufacturers take it out of the chambers when it acquires the specific gravity of 1,220, others let it remain till it

becomes 1,500. It is concentrated in the leaden boilers up to 1,750, but then it must be removed into glass or other vessels.

Sulphurous Acid Water.

This acid is procured extemporaneously by burning brimstone in a closet for bleaching straw hats, or by taking a rag, dipped in melted brimstone, and burning it in the cask to stop the fermentation of wine; but the neatest process is to prepare the acid water, formerly called, in the Pharmacopœia, gas sulphuris.

One pound of wood shavings is put into a glass retort, and there is then added a pound of oil of vitriol: to the retort, placed in a sand-pot, is then luted a receiver, containing sixteen pounds, or two gallons of water, to receive and condense the acid gas, the fire is then lighted and the distillation continued to dryness.

Some use saw-dust, chopped straw, or charcoal dust, instead of wood shavings, but these are apt to get lumpy; for theoretical purposes, quicksilver or tin is employed, by which the admixture of carbonic acid is avoided.

Instead of a retort and receiver, a glass matrass and a bent hollow glass cane, forming a communication with a bottle or jar, may be used.

The proportion of water stated above, causes the acid to be of a proper strength for bleaching, but some prefer putting only four pounds of water into the receiver, and thus procure a less bulky product, which they afterwards weaken with more water, if it is to be used for bleaching, but for stopping the fermentation of wine the strong acid is preferable.

This acid is also used for discharging stains and iron moulds from linen. It must be kept in small, well-stopped bottles, or used soon after it is made: for the action of air speedily changes it into sulphuric acid.

Berthier produces this acid by heating one ounce of sulphur with eight of black manganese; receiving the gas in water, as in the former process.

Liquid Sulphurous Acid.

This acid is obtained by distilling oil of vitriol with quicksilver, or tin, and passing the gas through a hollow glass cane, filled with muriate of lime, into a small matrass, surrounded by a freezing mixture of two parts of ice and one of common salt.

This acid is so extremely volatile that it may even be used to produce so intense a degree of cold, that M. Bussy has condensed, by its means, not only chlorine gas, and ammoniacal gas, but also cyanogen.

NITRIC AND NITROUS ACIDS.

The nitric and nitrous acids are usually confounded together, and, indeed, are prepared by the same process, and mixed together. Nor is this mixture of any detriment to the generality

of operations in which they are employed, for the nitrous acid is changed, during the operation, into the nitric.

They are distinguished by the manufacturers into several kinds, according to their mode of preparation. If made by distilling saltpetre with copperas, it is called *aqua fortis;* if with clay, a process not now used in England, *spirit of nitre;* if with oil of vitriol, *Glauber's spirit of nitre*, or *nitrous acid;* if this is rendered colourless by boiling, *nitric acid.*

The processes for preparing these acids remain the same as at their first invention, and do not seem to admit of any improvement.

Aqua Fortis.

To obtain the common nitric acid called aquafortis, equal parts of well purified nitre and copperas, or green vitriol, are taken. The nitre is dried, and the vitriol is calcined to redness. These two substances are well mixed together. The mixture is then put into an earthen retort, or an iron pot, with a stone-ware head, of such a size that they may be but half full.

The retort, if used, is set in a reverberating furnace, and in either case, a large glass receiver, having a small hole in its body, stopped with a little lute, or a safety-pipe, is applied. This receiver is luted to the retort with the fat lute. and the joint covered with a slip of canvass, smeared with lute made of quicklime and the white of an egg. The vessels are heated gradually; the receiver is soon filled with very dense red vapours.

In order that the redundant vapours may be let out, the small hole in the receiver must be opened from time to time. Towards the end of the operation, the fire must be raised so that the vessel is made red. When it is found, even if the retort be red hot, that nothing more comes over, the vessels are left to cool, and the receiver is unluted, and, without delay, the liquor it contains is poured into a bottle.

This liquor, being nitrous acid, is of a reddish-yellow colour, smokes exceedingly, and the bottle containing it is constantly filled with red fumes, like those observed in the distillation.

By this process a very strong and smoking spirit of nitre is obtained. If the precautions of drying the nitre, and calcining the vitriol, be neglected, the acid that comes over, greedily attracting the water contained in these salts, will be very aqueous, will not smoke, and will be almost colourless with a very slight tinge of yellow, and is sold by the name of single aqua fortis.

The fumes of highly concentrated nitrous acid, such as that obtained by the above process, are corrosive, and very dangerous to the lungs. The person, therefore, who unlutes the ves-

sels, or pours the liquor out of the receiver into the bottle, ought, with the greatest caution, to avoid drawing them in with his breath; and, for that reason, ought to place himself so that a current of air, either natural or artificial, may carry them off another way. It is also necessary that care be taken during the operation, if you do not use a safety-pipe, to give the vapours a little vent every now and then, by opening the small hole in the receiver; for they are so elastic that, if too closely confined, they will burst the vessels.

When the operation is over, a red mass is left at the bottom of the retort, cast as it were in a mould.

The ferruginous basis of the vitriol, which is mixed with this salt, the sulphate of potasse, gives it the red colour. To separate the sulphate from the mass, it must be pulverized; dissolved in boiling water, and the solution filtered several times, to separate the red oxide of iron, which being very finely divided, is sold for polishing metals, under the names of colcothar, trip, or rouge. When the solution is very clear, and deposites no sediment, it is set to shoot, and will yield crystals of sulphate of potasse, to which a German physician gave the name of sal de duobus, but which is sold now under the name of sal enixum, a name given to it by Paracelsus.

Spirit of Nitre.

The foreign distillers of aqua fortis, who make large quantities at a time, and who use the least chargeable methods, do their business by means of earths holding a quantity of sand, such as clays and boles. With these earths they mix the rough saltpetre, from which they intend to draw their spirit. This mixture they put into large oblong earthen pots, having a very short curved neck, which enters a receiver of the same matter and form.

These vessels they place in two rows, opposite to each other, in long furnaces, and cover them over with bricks, cemented with loam, which serves for a reverberatory. Then they light the fire in the furnace, making it at first very small, only to warm the vessels. They then throw in wood, and raise the fire till the pots grow quite red hot, in which degree they keep it up till the distillation is entirely finished.

The acid obtained in this process is less highly coloured than the acid obtained by copperas, and, as rough saltpetre is usually employed, it contains much muriatic acid.

The residuum is, in France, ground to a powder, and used as a red sand, in the alleys of artificial gardens, to vary the colours of the paths; it is also used in cements.

Glauber's Spirit of Nitre, or Nitric Acid.

The acid of nitre is also commonly separated from its basis

by means of the pure sulphuric acid. For procuring it in a small quantity, refined saltpetre is finely pulverized, put into a glass or stone-ware retort, and a third, or rather half of its weight of concentrated oil of vitriol poured on it. The retort is placed in a furnace, and a receiver expeditiously applied.

As soon as the oil of vitriol touches the nitre, the mixture grows hot, and copious red fumes begin to appear. Some drops of the acid come over even before the fire is kindled in the furnace.

On this occasion the fire must be moderate; because the vitriolic acid being clogged by no basis, acts upon the nitre much more briskly, and with much greater effect, than when it is not pure.

This operation may be performed by a sand heat, which is a speedy and commodious way of obtaining the nitrous acid. In other respects, the precautions recommended in the process for aqua fortis, must be carefully observed here, both in distilling the acid, and in taking it out of the receiver.

This spirit of nitre may also be prepared in an iron pot with a stone-ware head, and a receiver of the same ware; but there should be a white glass adapter between the head and receiver, that the progress of the operation may be seen.

The French now distil it in large cast-iron cylinders, the same apparatus as is hereafter described for preparing the muriatic acid, except that four cylinders are usually heated by the same fire, and only three or four receivers attached to each.

When distilled in an iron vessel, a greater portion of the product is in the state of nitrous acid than when distilled in glass or stone-ware with no more heat than is necessary. To obtain the real nitric acid, it is only necessary to heat the acid in a glass retort, until it becomes as clear as water, by the flying off of the nitrous gas.

The quantity that is condensed in water during the distillation of this acid spirit, when Glauber's apparatus is used, is, as Mr. Woulfe observes, so small that it would be scarcely worth saving, if it was not to prevent those noxious fumes of nitrous gas which have such an effect on the lungs of the operator, as frequently to make him spit blood. Water highly charged with these fumes by repeated distillations becomes blue, and retains its colour. Mr. Woulfe distilled, in an iron body with a stone-ware head, thirty pounds of nitre, with sixty pounds of green vitriol, which he had calcined to whiteness, and made use of two vessels of water, as in fig. 147, to condense the vapours. This water became blue in one distillation, and continued so for eighteen months till he made use of it. A great quantity of gas was set free from the beginning to the end of the distillation, owing, in a great measure, to the acid fumes acting on the iron

body; for if distilled in a glass or stone vessel, the quantity of this gas is not near so considerable. The water in which these nitrous fumes were condensed, saturated more alkali than the strongest oil of vitriol. The water was not heated by these fumes.

When oil of vitriol was used in this operation to set free the acid of nitre, Mr. Woulfe found on trial the fumes condensed in the water to be pure spirit of nitre; whereas, in the other operation, where calcined vitriol or copperas was used, the fumes contained some acid of salt. This led him to examine the common English green copperas, and he found it contained a portion of iron united to the acid of salt; whereas the Dantzic copperas or vitriol, contains no acid of salt; and this is the reason why it is preferred for making aqua fortis for the refiners' use, and for dyeing certain colours; and still used by the Dutch and some English manufacturers instead of the common copperas.

[The English manufacturers now procure the aqua fortis, or nitric acid, of commerce almost exclusively by the direct action of sulphuric acid on the nitrate of potash. The indirect method of obtaining this article from nitre and the green copperas, is more expensive at the present low prices of sulphuric acid, and the product is never so pure. When nitre is heated with calcined per sulphate of iron, a portion of the acid is decomposed and resolved into nitrous acid and oxygen: the latter unites with the iron, converting the protoxide into a peroxide, and the former passes over into the receiver along with the nitric acid, imparting to it a reddish colour, and the fuming property mentioned in the preceding article.

The cylinder is found to be the most useful form for the retort, both for distilling the nitric and the muriatic acids, on account of the greater convenience of removing from it the materials remaining in the retort after distillation. But a decided improvement on the French cylinder, as represented in fig. 236, has been introduced by an English manufacturer, which secures the advantage of the cylindrical form, and obviates, in a great degree, the objection to the employment of iron vessels. This improvement consists in constructing the upper half of the cylinder of bricks laid in Roman cement. Fig. 236 represents a front elevation of two retorts constructed on this plan; *a a*, the retorts, which are usually made six feet long, and one foot six inches in diameter in the clear; the lower half are of cast-iron, about one and one-half inches thick; these semi-cylinders of iron have horizontal flanges, *c c c c*, running the whole length of the retort, and about four inches wide: these flanges are slightly turned up at the edge, and constitute abutments, from which an arch of brick work is sprung, which forms the upper half of the retort, and completes the cylinder. The cylinders are sup-

rted only at the ends, and set in such a way as to allow the e to come in contact only with the iron surface; the brick ork above is left exposed so as to allow the operator to detect y leakage, which may occur during the operation. The ends f the retorts are closed by iron lids, and the arrangements in very other respect are quite similar to those delineated in g. 104.

The cheapest receivers on a large scale are fabricated of fine ay, and glazed with common salt, forming that species of pot- ry which is generally known in this country by the name of tone-ware; the best form is that of a cylinder set on end, with wo patulous lipped tubulures at the top for the reception of tubes of the same material twice bent at right angles, by which the receivers are connected together. The receivers may con- ain from 12 to 20 gallons each, and cost one shilling and six ence sterling per gallon in England. About 12 receivers are sually connected with each retort of the above dimensions. The junctures are all secured with Roman cement. 350 pounds f crude coarse nitre are put into each retort, and after the iron nds are luted in, 210 pounds of concentrated sulphuric acid are ntroduced through a tubulure in the upper part of the lid, or nd, by means of a leaden funnel, with a long bent tube, which onducts the acid to the middle of the retort, from which it ay flow equally to either end. The tubulure is then stopped nd luted. Previously, however, to the introduction of the cid, the first receiver of the series is connected with the re- ort by means of an earthen pipe, and the receivers with one nother. No water is put in the first five receivers: into the emaining seven, 32 gallons of water are introduced and dis- ributed as follows: 2 gallons in the sixth, 3 in the seventh, 4 in he eighth, 5 in the ninth, and six gallons in each of the remain- ng three: no water is put in the first receivers, in order that the roduct may be more free from nitrous acid, for the more concen- rated the nitric acid is, the less nitrous acid will be absorbed. The same reason obtains for using the concentrated instead of diluted sulphuric acid in the distillation.

It is very important to the success of this distillation that he nitrate of potash be free from the muriate soda, a very com- non impurity. A ready test of the purity of nitre in this res- ect is afforded by the action of sulphuric acid upon it when old; if the salt effervesce on the addition of concentrated oil f vitriol, the presence of muriate of soda is altogether proba- le; if a solution of the salt give a white precipitate with the itrate of silver, there can be little doubt of the fact: the mu- iate of potash and other salts might afford the same results, ut they are rarely present in the nitre of commerce. The nuriate of soda not only contaminates the product, but frequent-

ly occasions such an effervescence of the materials in the retort as to drive over the mixture and ruin it altogether.

In order to secure a little pressure on the mixture in the cylinder, the diameter of the pipe connecting the two last receivers in the series should not exceed one inch: the diameter of the other connecting tubes (in the clear) should be about 2 inches.

After the distillation is finished, the specific gravity in the five first receivers, will range from 1.460 to 1.475. The product in the last seven receivers will be of various specific gravities, and is used to dilute that in the first four. The acid in the first receiver should never be sold by the manufacturing chemist, and is usually reserved for other processes of chemical manufacture. That in the other receivers is very free from sulphuric acid, but is contaminated to a greater or less degree, with nitrous acid. In order to remove this impurity, reduce the acid to 1.380, by the addition of water, or by the mixture of the weaker with the stronger products of distillation, pour it back into the receivers and expose them to the heat of a hot water bath for 10 or 12 hours. Some chemists fill the receivers to within six inches of the top, and connect them by the bent tubes with others containing eight gallons of water each, by which the nitrous acid is condensed and saved; or where there is an oil of vitriol chamber, the fumes of nitrous acid may be profitably conducted into that, and thereby make a considerable saving of nitre.

The nitric acid of commerce is sold under the name of single, double, and triple, aqua fortis; the first should have a specific gravity of 1.180, the second, of 1.320, the third, of 1.360, or reckoning on Twedale's hydrometer, the numbers should be 36°, 64°, and 72°. The caput mortuum, after the distillation of nitric acid, was formerly known and still goes by the name of sal enixum with the practical chemists. It consists for the most part, of the sulphate of potash, a salt for which there is some demand for the calico printers. To prepare this salt, put into a leaden boiler capable of holding 25 gallons, 15 gallons of water, 28 pounds of sal anixion, and 18 pounds of sulphuric acid; boil this mixture, and then add as much more of the salt and acid in the above proportions as will be necessary to raise the liquid to the specific gravity of 1.200; while hot, run off the liquid into a leaden vessel, and when the foreign matters have subsided, pour the clear liquor back into the boiler and evaporate to 1.500 (when cold, i. e. at 60°.) Lastly, lade the liquor into a leaden pan sitting upon the warm brick-work, and suspend in it slips of lead; allow the liquor to cool very slowly; the crystals of super-sulphate of potash will form upon the slips of lead and the sides and bottom of the pan. It is important that the cooling should be gradual, as otherwise there

will be instead of crystals a pasty pulpy mass. The mother water is unfit for use a second time, on account of the presence of iron. For other dispositions of the sal anixion, see the articles muriatic acid and alum, in this work.

Pure Nitric Acid.

The nitric acid extracted by Glauber's process is as strong as that obtained by calcined vitriol, provided the oil of vitriol made use of be well concentrated; but it is also generally tainted by the admixture of a small portion of the sulphuric acid, which is carried up by the heat, and if the saltpetre was not properly refined, with muriatic acid.

There are several processes in chemistry that succeed equally well whether the nitric acid be or be not thus adulterated with a mixture of the sulphuric acid. But most experiments require the nitric to be absolutely pure; and if it be intended for such, it must be perfectly cleansed from the sulphuric taint.

This is generally effected by mixing the acid with very pure saltpetre, and distilling it a second time. The sulphuric acid, with which this spirit of nitre is adulterated, coming in contact with a great quantity of undecomposed nitre, unites with its alkaline base, and expels a proportionable quantity of the nitric acid.

The separation of the muriatic acid is more difficult; if the nitric acid is strong, it may be mixed with nitric solution of silver, which causes an insoluble muriate of silver to fall down as a sediment; but this will not answer well if the nitric acid is weak.

If, as some authors order, the impure nitric acid is mixed with nitric solution of silver, and distilled to dryness, the last portions of acid carry over with them some traces of the muriate of silver.

Another process has been tried to effect this purification by distilling the acid from the scaly yellow oxide of lead, called litharge. A process which has occasioned much discussion. M. Steinacher observes, that it has been long known that the last portions of nitric acid distilled on litharge contain muriatic acid.

Berthollet explains this phenomenon by saying that the oxide of lead dividing its action between the two acids, both are subject to the action of the expansibility produced by heat.

When the nitric acid has been sufficiently concentrated before it is submitted to rectification on oxide of lead, the first portion of the rectification contains no muriatic acid, notwithstanding the nitric acid contains much of the former before its concentration. The excess of water is the true cause that diminishes the attraction of the muriatic acid for the oxide of lead. It would, however, be vain to expect success in concentrating

the acid before it is rectified, by taking a certain quantity of litharge, or by distilling to dryness, as many authors have prescribed. The quantity of litharge ought to vary from one-sixteenth to one-half of the weight of the acid, according to its degree of impurity. On the other hand, by distilling to dryness the last portions of nitric acid, carry over with them muriate of lead. The following process may be useful to those who wish to prepare themselves the reagents with which they operate:

Eight pounds of nitric acid, at 35° containing muriatic acid, and a very small quantity of sulphuric acid, must first be distilled in a capella vacua. The fire also must be managed in such a manner that the drops may slowly succeed each other, and the distillation stopped when half the acid is come over. This rectified acid will mark 15° on Baumé's hydrometer. What is left in the retort is 40° of the hydrometer: throw into it litharge in fine powder, and stir it with a glass stick. A few hours are sufficient to convert the litharge into a white powder. Put in more, and keep adding farther quantities till you see that it preserves its colour after being immersed several hours. Then let the muriate and sulphate of lead entirely settle, and decant the acid into a glass retort set in a capella vacua, on a little sand, to keep it steady.

Adapt to the retort a receiver that fits exactly without being luted, for as the vapour of the acid easily destroys every kind of luting, the produce would be liable to be dirty, and conduct the distillation very slowly; yet care must be taken to keep the acid boiling, as it otherwise would disperse in vapours that could not be condensed. The first half that comes over marks 35° of Baumé's hydrometer, and the second 40. Both portions are colourless, and possess all the properties of very pure nitric acid, provided the precaution be observed to leave one-thirty-second of the liquid in the retort.

The following table, from a set of experiments which Dr. T. Thomson made with great care, exhibits the specific gravity of various atomic compounds of real nitric acid and water. One proportion or atom of acid with

1 of water . .	1,550
2 . . .	1,4865
3 . . .	1,4546
4 . . .	1,4237
5 . . .	1,3928
6 . . .	1,3692
7 . . .	1,3456
8 . . .	1,3420
9 . . .	1,3032
10 . . .	1,2844
11 . . .	1,2656
12 . . .	1,2495
13 . . .	1,2334
14 . . .	1,2173
15 . . .	1,2012

The acid compound, of one proportion of acid and four of water, seems to be the most intimate, for its boiling temperature is the highest, being 248°, while acid, both stronger and weaker than this, boils at a lower temperature. This is the strength of the acid usually sold, and 100 parts of it contains exactly sixty of real acid, and forty of water.

Acid of the specific gravity 1·3692, contains just half its weight of water; it boils at the temperature of 243°.

These boiling points were determined by Mr. Dalton.

Nitric acid is usually kept not only in a concentrated state, but also of a proper strength for the solution of silver without heat; that is, of the specific gravity 1,108, or so that a bottle that will hold sixteen ounces of water holds nineteen of the acid. Henry recommends analytical chemists to keep their acid at 1,143, so that it may have the same power of saturation as sulphuric acid, at 1,135.

Nitric acid is considered as a compound of one atom of azote, or nitrogen, with five of oxygen, or Az:::, and its proportional number, according to Thomson, is, 6,750. Berzelius considered it as a combination of nitricum and six volumes of oxygen, N:::, or 677,260, which is the same in effect, because he considers azote or nitrogen to be the oxide of a hitherto unseparated basis, which he calls nitricum.

Pure nitrous acid contains an atom less of oxygen, and its proportional number, is, of course, either 5,750, or 577,260. When mixed with water it is converted into nitric acid and nitrous gas.

What is commonly called nitrous acid is generally considered as merely nitric acid impregnated with nitrous gas; but it seems to be rather a mixture in various proportions of nitric and nitrous acids, the oxygen dividing itself between them.

The pure nitrous acid is not used.

MURIATIC ACID.

This acid is also called *the acid of common salt*, as it is always extracted from it; and as common salt is often made from sea water, the acid also got the name of *marine acid*. It is now called *hydrochloric acid* by the theoretical chemists.

The common salt from which the acid is to be extracted is put into a glass retort, leaving two-thirds of it empty. The retort is set in a furnace, and a receiver, with a hole in its side, applied and luted on. Then through the hole in the arch of the retort, a quantity of oil of vitriol, equal in weight to about a third part of the salt, is poured, and immediately the hole shut very close.

As soon as the oil of vitriol touches the salt, the retort and receiver will be filled with abundance of white vapours, and soon after, without lighting any fire in the furnace, drops of a yellow liquor will distil from the nose of the retort. The distillation is to proceed in this manner without fire, as long as any drops are perceived. A very small fire is next kindled under the retort, and the fire gradually raised by very slow degrees

and with great caution. The distillation will be ended before you have occasion to render the retort red hot. The vessels are then unluted, and the condensed liquor which will be found to be a very smoking spirit of salt, is kept under the distinctive name of Glauber's spirit of salt.

As oil of vitriol is used on this occasion, and as the sea salt is generally dried, the acid obtained from it by distillation is very free from moisture, and always smokes even more violently than the strongest acid of nitre. The vapours of this acid are also much more elastic and more penetrating than those of the nitrous acid.

This process requires a pierced retort, that the oil of vitriol may be mixed with the sea salt after the receiver is well luted to the retort, and not before. For as soon as these matters come together, the muriatic acid gas rushes out with so much impetuosity that, if the vessels were not luted at the time, the copious vapours that would issue through the neck of the receiver would so much moisten it, as well as the neck of the retort, that it would be impracticable to apply the lute and secure the joint as the operation requires. The operator would besides be exposed to those dangerous fumes which on this occasion rush out, and enter the lungs with such incredible activity as to threaten instant suffocation.

When the operation is finished, a white mass is left at the bottom of the retort, which is the sulphate of soda, or Glauber's salt.

Spirit of salt, drawn by the process above described, is tainted with a small mixture of the sulphuric acid, carried up by the force of fire before it had time to combine with the soda of the salt: in order to free it from this sulphuric acid, it must be distilled a second time from sea salt.

Brugnatelli, in making muriatic acid for theoretical purposes, uses eight ounces of dry common salt, and five of oil of vitriol, passing the gas through a bent syphon, containing muriate of barytes, to absorb the sulphuric acid that may distil over. He also puts eight ounces of water into the receiver; and finds that water absorbs 450 times its bulk of muriatic acid gas, by which the bulk of the water is augmented about one-third.

Three apparatus are used for manufacturing muriatic acid, on a large scale, from common salt and oil of vitriol.

Some manufacturers, both in England and France, use a cast-iron pot set in a furnace, instead of a retort. In England this pot is covered with a pierced stone-ware head, and connected with a large receiver of the same ware, in which water is placed. But in France the pot is covered with a plate of lead, screwed down upon it, and is connected with a row of seven or eight stone-ware bottles, by means of bent pipes. These bottles are each half filled with water.

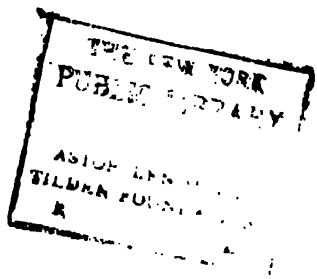

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Fig 103

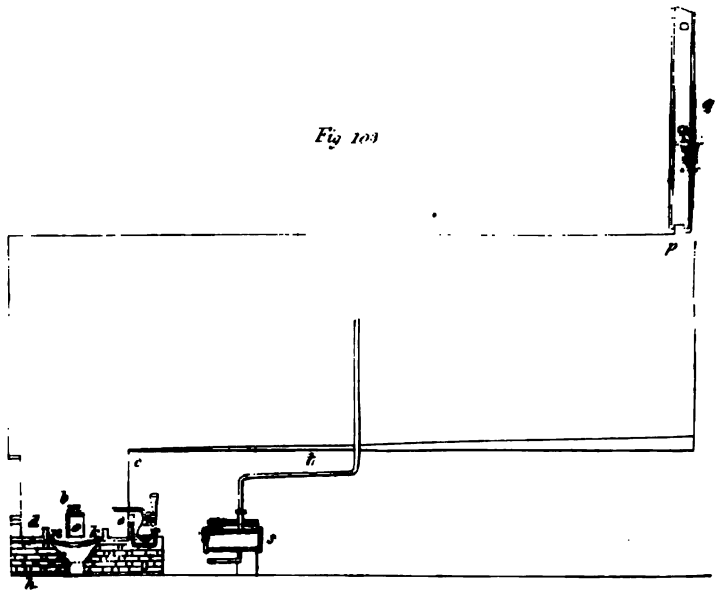


Fig. 104.

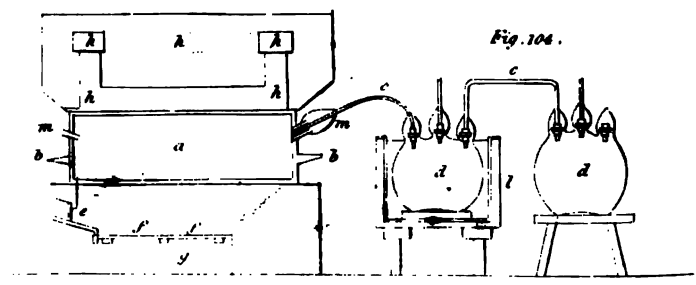
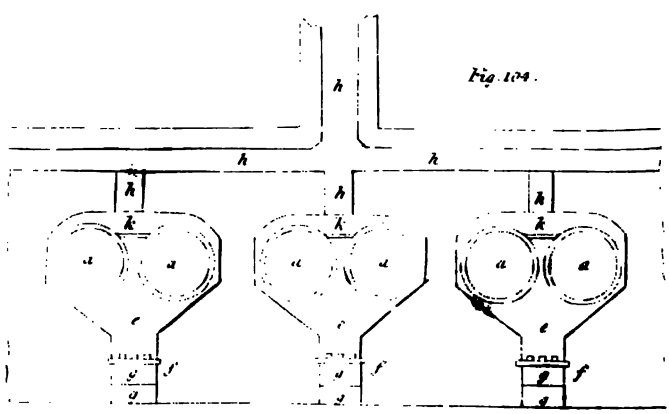


Fig. 104.



The salt being put into the pot and the head and receiver luted to it, or the plate of lead screwed down, and the pipes luted to it and the bottles, the oil of vitriol is poured by a funnel through the hole left for the purpose.

This method is subject to the inconvenience of the saline residuum concreting so fast to the bottom of the pot that it is very difficult to be detached.

The second apparatus is used in France, and called by the French the appareil des bastringues. It is connected essentially with the manufactory for mineral alkali, and the muriatic acid is only a secondary product.

At the back of a reverberatory furnace with a chamber on the side, as in fig. 14, a large leaden pan, about six feet long, five feet wide, and a foot deep, is set in the brick-work and covered with plates of cast iron, level with the lower edge of the flue coming from the chamber, so that the flame, &c. passes over these plates, then under the pan, and up the sides, from whence they enter the flue of the chimney, of course the pan is heated by the waste heat of the furnace. An opening is left on one end of the pan, by which it is charged with salt, usually twelve sacks of two hundred pounds each, after which the opening is closed with care. Sulphuric acid at 54° Baumé, in the proportion of one hundred and ten pounds for each one hundred pounds of salt, is then poured in by a pipe. The vapours pass through four earthen-ware pipes into the condensors, which are seven or eight stone-ware vessels without bottoms, placed one upon another, so that the acid as it passes upon them may be condensed, and drip down to the lowest, whence it runs into the bottles in which it is sold.

At the expiration of a certain time, the opening at the end of the pan is unclosed, and the soft pasty residuum is drawn out, on a brick hearth, where it soon becomes solid: this part of the operation is very distressing to the laborants, on account of the muriatic acid gas which it continues to emit, as it is impossible to finish the decomposing the common salt entirely in this method, from the necessity of withdrawing the residuum while it is yet soft. In this process there is only obtained two-thirds of the acid contained in the salt, or about eighty or ninety pounds of weak acid at 21° Baumé, from each one hundred pounds of salt.

Some manufacturers instead of aludels use long troughs of brick-work, or subterranean sewers, lined with glazed tiles, and having a current of water running through them in a contrary direction to the passage of the vapours; but this was for the purpose of getting rid of the acid, when it was produced in a greater quantity than the market required.

The third apparatus is an extension of the use of cylindrical

iron long necks instead of retorts, which have come so much into use in manufactories.

A furnace, fig. 104, is constructed capable of containing twenty cylinders, *a*. They are made of cast iron, of a homogeneous texture, and uniform thickness, in order to prevent unequal expansion and cracks. They are placed in pairs in the furnace, and each pair has its fire-place, *e;* grate, *f;* and ash-room, *g;* somewhat like the apparatus for making coal gas. Every part of the cylinder should be equally heated, in order that the decomposition of the salt may be simultaneous, and the iron be as little as possible injured by the acid. For this purpose, a plate of cast iron, *k*, is placed between the cylinders; and the flues, *h*, are constructed so as to produce an equal draught through every part of the furnace. In proportion as the sulphuric acid contains less water, and in proportion as the cylinder is heated, it is less subject to be injured by the acid. The flame should envelope every part of the cylinder, and should be retained in the archway above it, to give out some of its heat before it flies up the chimney.

Each cylinder is closed at both ends by a plate of cast iron entering just within the cylinder, where it meets with a circular rim. Each plate has a handle of cast iron, *b*, and a small tube, *m*, projecting upwards, and being in the upper part, for the purpose, at one end, of pouring in the sulphuric acid, and conveying off the product at the other. The first cylinder communicates by the bent pipe, *c*, either of glass or earthenware, with the earthen vessel, *d*, which has three mouths, and again communicates by two other bent tubes, *c*, with two other vessels of the same description. All the gas not condensed in the first bottle, *d*, passes into the other bottle, and at the same time, the second bottle, *d*, receives the gas from the second cylinder, and transmits what it does not condense to another bottle of the same description, which in like manner also receives the gas from the third cylinder, and in this way the process goes on to the last bottle, which receives the gas not condensed in all the others, and, moreover, that which issues from the last cylinder. From this, whatever is not condensed is again transmitted through a second range of bottles, consisting, perhaps, of twenty, till the whole is condensed. It is proper to place the first range of bottles in a trough, *l*, through which a stream of water flows gently and constantly, cooling the bottles, and getting itself heated.

The purest muriatic acid is obtained in the second range of bottles. That which is condensed in the first series always contains a little sulphuric acid, and sometimes sulphate of soda and muriate of iron. All these bottles are to be half filled with water, which will absorb two-fifths of its weight of muriatic acid. By means of this apparatus, 130 parts of muriatic acid, of the specific gravity 1·190, may be obtained from 100 of common salt. Each cylinder is charged with about 160 pounds of common salt, and the end is then luted with clay, the fire is kindled, and the sulphuric acid poured on the salt, in the proportion of eighty pounds of acid, to 100 of salt; if the acid is concentrated to 66° of Baumé's areometer, and 83 to 100 if it is only concentrated to 64°. The fire should be made brisk at first, and be lessened immediately the distillation begins; when this slackens, the heat is increased; afterwards, the end is removed, the sulphate of soda taken out, and the process is then repeated. By means of syphons, the muriatic acid is drawn into bottles, or jars, covered with basketing; its strength is 23° of Baumé, and in this state it is sent into the market.

[The cylindrical retorts already described in the preceding article (see also Fig. 236) are preferable to those composed wholly of iron for the distillation of muriatic, as well as for the nitric, acid. They combine the peculiar advantages of the cast-iron pots with stone-ware, or leaden caps with those of the iron cylinders. The same kind of receivers also, as recommended in the distillation of nitric acid will be found very convenient and economical for this purpose. Fig. 237 exhibits a ground view of the manner in which the receivers may be arranged and connected together for this purpose; *a a* are the earthen tubes leading from two cylinders and terminating in the receiver *b;* this receiver is connected with the usual bent earthen tubes with the receiver *c*, this last with *d*, and so on through the series, which terminates in the receiver *e*. About 20 re-

Fig. 236.

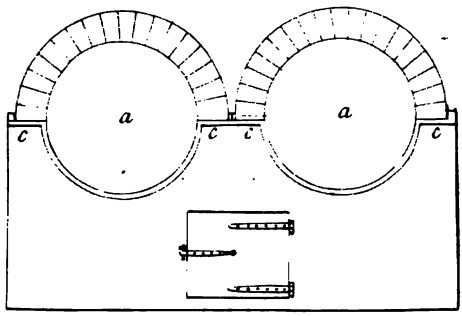
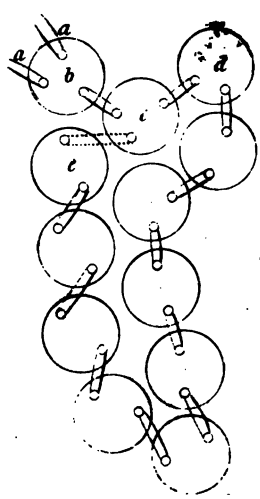


Fig. 237.



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R L

ied for two cylinders, and, if the establishment be sufficiently
nore cylinders, it is better that each pair should be furnished
ies of receivers. Five hundred and seventy pounds of coarse
id five hundred pounds of concentrated sulphuric acid are put
-The salt is introduced first as in the distillation of nitric acid,
s are cemented in, and the junctures throughout the appara-
re with Roman cement, (six gallons of water being previously
ach of the receivers except the two first in the series) the acid,
the heat raised suddenly to the required point. The same pre-
y to deposite the acid near the centre of the retort, from which
:ach way, as directed in the distillation of nitric acid; if this pre-
d, and the acid be allowed to accumulate at either end, the ef-
e the heat is applied will drive all the salt to the opposite end,
ition will be liable to be incomplete. As the tubes in none
re allowed to terminate below the surface of the liquid in them,
on whatever for safety tubes in this apparatus.
illation the receivers, beginning with the third, become hot, and
ively as the absorption progresses, and the water becomes sa-
1 the last receiver has become hot and cool again, we may in-
:ss is finished.
om the above quantities of materials should be about 14 cwt.
ic gravity of 1.170 to 1.175. The usual commercial strength
1.160.
in the two first receivers, and therefore very little muriatic acid
iem. They serve to condense and receive the sulphuric acid,
:d during the process. There is a particular advantage in hav-
:s in the second receiver; towards the last of the distillation, the
:cessarily raised so high that a considerable proportion of sul-
atilized, and more than can be condensed in the two first re-
ay the whole product is liable to be contaminated. To avoid
vers are so arranged that the last of the series shall approach
:ond receiver as they do to each other generally, and towards
)cess the communication between the second and third receiv-
withdrawing the connecting tube, and closing the apertures,
:eiver and the last of the series are connected as indicated by
n Fig. 237. In consequence of this arrangement the last re-
:he number and capacity of receivers be sufficiently large, will
slightly, if at all, impregnated with muriatic acid, and will ab-
)e the whole of the volatilized sulphuric acid, which would
ributed through the series and contaminate the whole product.
the order of the process is productive of no inconvenience
the trouble of withdrawing and inserting the tubes as directed;
)perator will execute with very little loss of gas or risk to him-
: allowed to burn low before the operation be attempted, and
)n with the receiver *e* be formed before that between *c* and *d*

ncement of the first distillation, where the cylinders are new
suddenly raised so high as to occasion a violent effervescence
)y which means the brick portion of the cylinders becomes coat-
; of salt, which ensures their tightness. If a portion of the ma-
out of the cylinder by this operation, it is of little consequence,
condensed in the first receiver, and may be returned to the re-
d operation.
concentrated acid is required, Clement's absorbing cascades
may be employed, but a more concentrated acid than can be
y the above more simple method is rarely required, and is not
keeping.
remaining in the retorts after the distillation of the muriatic
re usually disposed of by the English manufacturer in the fol-
two parts of the former and one of the latter are mixed with
ed lime, and one of slack (small coal) and thrown into a rever-
; they are melted and stirred till the flame proceeding from

them nearly ceases, and the blackness disappears, and then drawn off into moulds. This product is sold to the soap boilers, and to them only under the name of rough barilla. For another disposition of the caput mortuum after the distillation of muriatic acid, as well, indeed, as for the sal enixum, the reader is referred to the article *alum* in this work.]

Uses of Muriatic Acid.

The muriatic acid is used to mix with nitric acid, in order to enable it to dissolve gold and platinum; to scour metals; to prepare muriate of tin for the dyers, to extract the phosphate of lime from bones; to mix with salt and saltpetre, to preserve flesh provisions, and several other purposes.

Theoretical chemists keep the acid highly concentrated; but for medical purposes, the spirit of salt is sold at about the specific gravity of 1,170, or so that an ounce measure may saturate 124 grains of sub-carbonate of soda, that being the strength ordered by the College. Henry, for analyses, recommends it to be kept at 1,074, so that it may saturate the same quantity of alkaline liquors, as sulphuric acid at 1,135.

Dr. Thomson has latély given the following statement of the specific gravity of muriatic acid of various strengths.

One proportion, or atom of acid, with	6 of water	1,203
	7 - - -	1,179
	8 - - -	1,162
	9 - - -	1,149
	10 - - -	1,139
	11 - - -	1,1285
	12 - - -	1,1197
	13 - - -	1,1127
	14 - - -	1,1060
	15 - - -	1,1008
	16 - - -	1,0960
	17 - - -	1,0902
	18 - - -	1,0860
	19 - - -	1,0820
	20 - - -	1,0780

The composition of muriatic acid is differently stated. Berzelius, in his Proportions Chimiques, considers it as the combination of the hitherto unseparated muriatic radical, with two proportions of oxygen, or M··, and its equivalent number as 342,650. On the other hand, Gay Lussac, Sir Humphry Davy, and their followers, consider it as a hydro acid, formed of one proportion each of chlorine and hydrogen, or Cl H, and hence Thomson states the weight of the muriatic acid gas at 4,625. Water is capable of absorbing 418 times its bulk of this gas, but the most permanent combination seems to be that of sixteen proportions of water to one of muriatic acid, as it sustains the greatest heat, namely, 232° Fahrenheit, before it boils.

OXYMURIATIC ACID.

This is the *dephlogisticated marine acid* of its discoverer, Scheele, the *oxygenated muriatic acid* of the old French nomenclature, and the *chloric acid* of the new French nomenclature. Its acid properties are but slight in some respects, although

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Fig. 105.

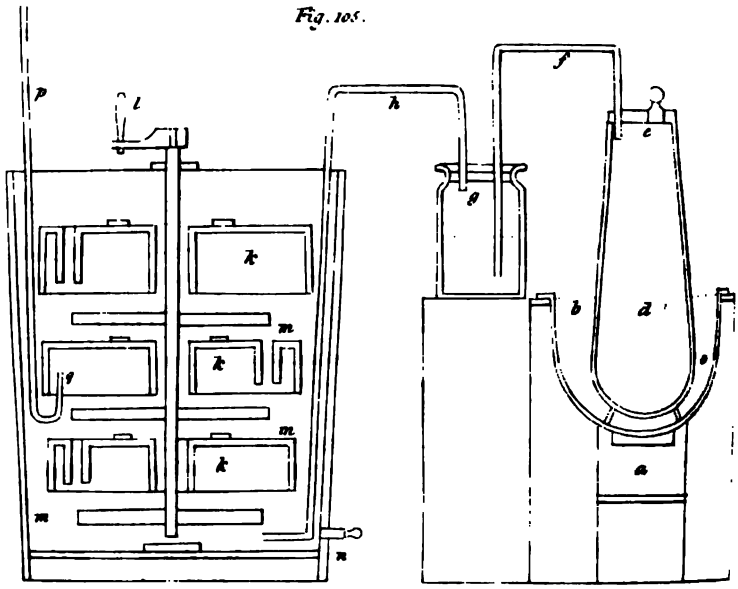
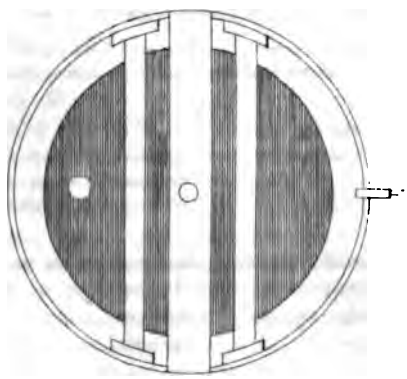


Fig. 106



very powerful in others. It entirely destroys the blue colours of vegetables, rendering them yellowish white, even those which resist the power of other acids; hence it is used in bleaching linen and paper, and is sold under the name of *bleaching liquor*. It has also an astringent taste, instead of the usual sour taste of most acids.

Fig. 105, is the elevation of Berthollet's apparatus for preparing oxygenated muriatic acid, with some alterations, as adopted in England, in which is represented a furnace, *a*, having set in it an iron kettle, *b*, with a trivet, *c*, on which is placed a body, *d*, cast of new lead, as the acid acts powerfully on tin, and, therefore, neither old lead, sheet lead soldered, nor pewter, can be used. Some use stone-ware bodies.

The mouth, *e*, of the body, is closed by a waxed cork, or leaden stopper, with two holes, through one of which passes a leaden, pipe, *f*, which forms a communication between the inside of the body, *b*, and the intermediate stone-ware jar, *g*, where it also passes through a waxed cork, or leaden stopper, which closes the mouth of that jar: the other hole, *e*, has a plain stopper. If corks are used, they ought to be prepared beforehand, and well fitted to the mouths of the body and jar, and the holes also well adapted to the pipes, which must be luted first with fat lute, and the joints then covered with strips of linen smeared with cheese and lime lute.

The intermediate vessel, *g*, is filled about an eighth part with water, and communicates by the pipe, *h*, with the tub, *i*. This pipe reaches to the bottom of the tub, where it is bent horizontally, so that the gas may be emitted under the first of the three wooden, or, if they can be procured, stone-ware cavities, or gas receivers, *k*, which are placed in the inside of the tub, one above the other. *l*, is a handle which serves to turn the agitators, *m*, the movement of which facilitates the combination of the gas with the water; *n*, is a spigot and faucet, to draw off the liquor.

Fig. 106, represents the manner in which the gas receivers, if of wood, are kept down in the water of the tub, by means of two bars, pinned by wooden pegs to certain projections within the tub.

Each cavity, *k*, in fig. 217, is so constructed that it may receive the gas which is emitted from the pipe, *h*. The gas, as it comes out, is collected under the lowest cavity, and increases in quantity until it passes by the funnel, *o*, to that in the middle, and afterwards to the upper end. The opening through which the agitator, *l*, passes, in the centre of each cavity, is in the shape of a funnel: and is so formed as to hinder the gas from escaping along the agitator, which is furnished with three transverse arms, *n*, fastened by a wedge.

The bent tube, *p*, serves to draw off the atmospheric air which is contained under the cavities, after the tub has been filled with water. To make use of this tube, the bent part is successively introduced under each cavity, as shown at *q*. It must then be blown into, at the end, *p*, till the water in it is forced out; then, on ceasing to blow, the air contained under the cavity will immediately make its escape.

Some manufacturers conceive this apparatus as too complex for the use of a manufactory, and think that a range of four, five, or six hogsheads, or rum puncheons, connected with one another in the manner of Woulfe's distilling apparatus, is preferable to either of them. Agitators on M. Berthollet's principle, may be applied. The retort, or matrass, should be of lead, standing in a water bath: its neck should be of sufficient length to condense the common muriatic acid, which always comes over; and it should have an inclination towards the body of the retort, so that the condensed acid may return into it. The liquor

is always the strongest when the distillation is carried on very slowly; and the strength is considerably increased by diluting the vitriolic acid more than is usually done. The following proportions are said to afford the strongest liquor:—three parts of manganese; eight parts of common salt; six parts of oil of vitriol; and twelve parts of water. The proportion of manganese is subject to variation according to its quality. Manganese, which has been used for the production of oxygen, answers equally well as fresh manganese.

The absorbing and productive cascades, is an apparatus invented and employed by M. Clement, a celebrated French chemist of the present day, to promote the absorption or solution of gases, and particularly applicable to the preparation of this acid; it is known that absorption takes place in proportion to the pressure on the absorbing liquid, the extent of surface exposed to the absorbing action, and to the length of time in which it is exposed. If the pressure, however, is very great, the vessels are apt to burst, and, therefore, in general, the object chemists have had in view has been to strengthen the influence of the two other principles we have just mentioned.

Fig. 107, represents M. Clement's apparatus; *a*, *b*, is a long cylinder full of a great number of small glass or porcelain balls, about one-third of an inch in diameter. This cylinder is fixed in another of a much greater diameter, in which a hole, *c*, is made corresponding to the lower extremity of *a*, *b*, and with which two small pipes, *d*, *e*, communicate; one being intended to introduce the gas, the other to empty the liquid. A stream flows from a cistern, *f*, by means of the pipe, *g*, which has a cock, so that this stream may be regulated at pleasure. The water in its descent is detained by all the little balls, which it wets successively, and is a considerable time before it reaches the bottom: on the other hand, as the gas arises, it occupies all the empty space, is much divided and subdivided; and as it also is detained in its progress upwards, the time it is in contact with the water, is so very considerable, that the author of this invention supposes it is more than three hundred times more efficacious in promoting the absorption of a gas, than the ordinary apparatus. This he calls the absorbing cascade.

To this apparatus he connects another, which he calls the productive cascade. It is intended to produce gas for a considerable period of time, and in a more convenient and less expensive manner than by the ordinary methods. Thus, for the present purpose of preparing oxymuriatic acid, a large vessel, *k*, provided with four openings, or holes, is filled with the oxide of manganese broken into large pieces. The mouth, *i*, is connected with a leaden bottle, *k*, containing common salt and sulphuric acid. A small stream is made to flow by the tube, *l*, from the cistern, *m*, which gradually moistens the whole surface of the pieces of manganese, and permits the muriatic acid gas to attack and dissolve them very easily. The oxymuriatic acid gas which is produced, passes by the pipe, *n*, into the absorbing cascade, while the muriate of manganese is carried off as it is formed along with the water through the pipe, *o*, into the jar, *p*.

By using this apparatus there is no occasion to reduce the manganese to powder, and a much larger quantity may be operated on at the same time without the operator being under the necessity of frequently renewing the charge of materials, and dismounting his apparatus.

Oxymuriatic acid has only been used in bleaching linen and paper; but at present, the use of oxymuriate of lime, or bleaching powder, has been preferred for the former manufactory.

Each avoirdupois pound of common salt furnishes in general, oxymuriatic acid (or chlorine) gas sufficient to saturate about four pints, or half a gallon of water. The tub containing the acid should be kept covered, to prevent the day-light from changing it into common muriatic acid. It freezes at 40° Fahr. the ice being in deep yellow crystalline plates, containing more of the gas than the liquid acid, and hence when they melt, an effervescence is produced by the escape of the surplus of the gas.*

Oxymuriatic Acid Gas.

This is the *chlorine gas* of the newest nomenclature, and is used for destroying the miasmata which are the cause of typhoid and remittent fevers.

For this purpose a mixture of black manganese, salt, and oil of vitriol, as for preparing bleaching liquor, is put into saucers, which are placed over chafing dishes in the rooms or churches which are to be disinfected. The rooms are shut up for a few hours, then opened and ventilated as much as possible before they are used.

M. Guyton de Morveau proposed a portable apparatus for disinfecting sick rooms, consisting of a very strong ounce and half stoppered bottle, in which is put forty-five grains of coarse powder of black manganese, and one hundred grains of nitric acid, at 17° Baumé. The stopper is kept down by the bottle being enclosed in a wooden case with a screwed top. On taking out the bottle, and loosening the stopper for a moment, until the smell of oxymuriatic acid gas is perceived, the miasmata in the neighbourhood of the bottle will be destroyed.

This gas may be collected, but cannot be preserved over water, on account of that liquid slowly absorbing it: stoppered bottles must therefore be used for that purpose.

Oxymuriatic gas is supposed to be an elementary body, by some called chlorine, which, with hydrogen, form common muriatic acid, and which combines with several proportions of oxygen: but Berzelius considers it a combination of the muriatic radical with three charges of oxygen, or M:·, calls it *muriatous super oxide*, and states its weight as 442,650.

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* The liquid oxymuriatic acid, or watery solution of chlorine, is now entirely superseded in the art of bleaching cottons and linen by the chloride of lime or bleaching powder. In the article on the manufacture of this substance by the editor, the reader will find some remarks on the foregoing apparatus of M. M. Berthollet and Clement.—Am. Ed.

NITRO MURIATIC ACID.

The nitric and muriatic acids unite together chemically, and form compounds, varying in properties according to the proportions in which they are mixed: but which have not yet been properly investigated.

Baumé recommends two parts of nitric acid and one of muriatic acid for dissolving gold; but equal parts of the two acids for dissolving platinum; both which metals are not dissolvable in either of the acids when separate.

If the acids are both concentrated they effervesce very violently for some time after they are mixed, and much of the acids fly off.

The theory of the change in the properties of the acids by their mixture is a disputed point in chemistry.

Nitro muriatic acid is confounded, by the theoretical chemists, with aqua regis.

ACETIC ACID.

Acetic acid is found combined with potash in the juices of a great many plants. Almost all dry vegetable substances, and some animal, subjected in close vessels to a red heat, yield it copiously. It is the result likewise of the spontaneous fermentation, to which all liquid vegetable and animal matters are liable. Strong acids, as the sulphuric and nitric, acting on vegetable matter, produce the acetic acid.

It was long supposed, on the authority of Boerhaave, that the fermentation which forms vinegar is uniformly preceded by the vinous. This is a mistake. Cabbages sour in water, making sour crout; starch, in starch makers' sour waters; and dough itself, without any previous production of wine.

If by age the wine has lost its extractive matter, it does not readily undergo the acetous fermentation. In this case, acetification, as the French term the process, may be determined, by adding slips of vines, bunches of grapes, or green woods.

It has been asserted that spirit of wine, added to fermenting liquors, does not increase the product of vinegar; but this is a mistake, for Stahl observed long ago, that if roses or lilies are moistened with spirit of wine, and placed in vessels in which they are stirred from time to time, vinegar will be formed. He also informs us, that if after abstracting the citric acid from lemon juice, by crab's eyes (a carbonate of lime,) a little spirit of wine is added to the supernatant liquid, and the mixture kept in a proper temperature, vinegar will be formed.

Chaptal says that two pounds of weak spirit of wine, sp. gr. 0.985, mixed with 300 grains of beer yeast, and a little starch water, produced extremely strong vinegar. The acid was developed on the fifth day. The same quantity of starch and yeast, without the spirit, fermented more slowly, and yielded a weaker vinegar.

Wine Vinegar.

The following is the plan of making vinegar at present practised in Paris. The wine destined for vinegar is mixed in a large tun with a quantity of wine lees, and the whole being put into sacks, placed within a large iron bound vat, the liquid matter is pressed out.

What passes through is put into large casks, set upright, having a small aperture in their top. In these it is exposed to the heat of the sun in summer, or to the heat of a stove in winter.

Fermentation comes on in a few days. If the heat should then rise too high, it is lowered by cool air, and the addition of fresh wine. In summer the process is generally completed in a fortnight; in winter double the time is requisite. The vinegar is then run off into barrels, which contain several chips of beech wood to clarify it: in about a fortnight it is fit for sale.

Almost all the vinegar of the north of France being prepared at Orleans, the manufactory of that place has acquired such celebrity as to render their process worthy of a separate consideration.

The Orleans casks formerly contained nearly 200 gallons of wine, but at present only about half that quantity. Those which have been already used are preferred. They are placed in three rows one over another, and in the top have an opening of two inches diameter, which has a bung fitting close; there is another spill hole on the side to admit the air. Wine a year old is preferred for making vinegar, and is kept in adjoining casks, containing beech shavings, to which the lees adhere.

The wine thus clarified is drawn off to make vinegar. At the first setting up of a manufactory, so much good vinegar, boiling hot, is first poured into each cask, as to fill it up one-third of its height, and left there for eight days. Two gallons and a half of wine are mixed in every eight days, till the vessels are two-thirds filled. Eight days afterwards, ten gallons of vinegar are drawn off for sale, and the cask is again gradually filled. Thus each cask or *mother* yields twice its own admeasurement of vinegar in a year.

It is necessary that a third part of the cask should always be left empty.

In order to judge if the mothers work well, the vinegar makers plunge a spatula into the liquid, and if it brings up a white froth, the making of the vinegar is judged to succeed well; if red, they add more or less wine, or increase the temperature.

In summer the atmospheric heat is sufficient. In winter,

stoves heated to about 75° Fahrenheit maintain the requisite temperature in the manufactory.

The casks get filled with lees in about ten years, and require to be cleansed; and fresh casks must be mounted every twenty-five years.

If the vinegar is not clear, it is clarified by being put for some time in a cask filled with shavings of beech wood.

In some parts of France, private persons keep, in a place where the temperature is mild and equable, a vinegar cask, into which they pour such wine as they wish to change into vinegar, and it is always kept full, by replacing the vinegar, as fast as it is drawn off, by new wine.

To establish this household manufacture, it is only necessary to buy at first a small cask of good vinegar.

A slight motion is found to favour the fermentation of vinegar, and its decomposition after it is made.

Chaptal thus ascribes to agitation the operation of thunder; though it is well known that when the atmosphere is highly electrified, beer is apt to become suddenly sour, without the concussion of a thunder storm.

In cellars exposed to the vibrations occasioned by the rattling of carriages, vinegar does not keep well. The lees which had been deposited by means of isinglass and repose, are thus jumbled into the liquor, and make the fermentation re-commence.

The Dutch method of making Wine Vinegar is thus described by Boerhaave.

Two large wooden vats or hogsheads are chosen, and in each of these a wooden grate or hurdle, at a distance of a foot from the bottom, is placed. The vessel is set upright, and in the grate a moderately close layer of green twigs or fresh cuttings of the vine is placed. The vessel is then filled up with the foot-stalks of grapes, commonly called the rape, to the top of the vessel, which is left quite open.

The two vessels being thus prepared, the wine to be converted into vinegar is poured in; one is filled quite up, the other but half full. They are left thus for twenty-four hours, and then the half filled vessel is made quite full from the liquor of that which was before entirely so; this, in its turn, will be only half full.

Four and twenty hours afterwards the same operation is repeated and proceeded in, the vessels being alternately kept full and half full during the twenty-four hours, till the vinegar is made.

On the second and third day, there will arise in the half filled vessel, a fermentative motion, accompanied with a sen-

sible heat, which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half full, the fermentation is, by this means, in some measure interrupted, and is only renewed every other day in each vessel.

When this motion appears to have entirely ceased, even in the half filled vessel, it is a sign that the fermentation is finished; and, therefore, the vinegar is then put into casks, close stopped, and kept in a cool place.

A greater or less degree of warmth accelerates or checks this, as well as the spirituous fermentation. In France, it is finished in about fifteen days, during the summer; but if the heat of the air be very great, and exceed 25° Reaum. or 88° Fahr. the half filled vessel must be filled up every twelve hours; because, if the fermentation be not so checked in that time, it will become violent, and the liquor will be so heated, that many of the spirituous parts on which the strength of the vinegar depends, will be dissipated, so that nothing will remain after the fermentation but a vapid liquor, sour indeed, but effete.

The better to prevent the dissipation of the spirituous parts, it is a proper and usual precaution to close the mouth of the half filled vessel, in which the liquor ferments, with a cover made of oak wood. As to the full vessel, it is always left open, that the air may act freely on the liquor it contains; for it is not liable to the same inconveniences, because it ferments very slowly.

Malt Vinegar.

In this country vinegar is usually made from malt. By mashing with hot water, 100 gallons of wort are extracted, in less than two hours, from six bushels of malt. When the liquor has fallen to the temperature of 75° Fahr., four gallons of yeast are added. After thirty-six hours it is racked off into casks, which are laid on their sides, and exposed, with their bung holes loosely covered, to the influence of the sun in summer; but in winter they are arranged in a room heated by stoves. In three months this vinegar is ready for the manufacture of sugar of lead.

To make vinegar for domestic use, however, the process is somewhat different. The above liquor is racked off into pairs of casks placed upright, having a false bottom pierced with holes fixed a foot from their bottoms. On this a considerable quantity of rape, or the refuse from the makers of British wine, or otherwise a quantity of low-priced raisins is laid. The liquor is pumped into the other barrel every twenty-four hours, in which time it has begun to grow warm. Sometimes, indeed,

the vinegar is fully fermented without the rape, which is added, towards the end, to communicate flavour.

Vinegar is made at Ghent, in Flanders, from beer; in which the following proportions of grain are found to be most advantageous: 1880 pounds of malted barley; 700 of wheat; and 500 of buckwheat. These grains are ground, mixed and boiled, along with twenty-seven barrels of river water, for three hours: eighteen barrels of good beer for vinegar are obtained. By a subsequent decoction, more fermentable liquid is extracted, which is mixed with the former. The whole brewing yields about 750 gallons, English measure, of vinegar.

Common vinegar has, sometimes, sulphuric acid fraudulently mixed with it, to give strength. This adulteration may be detected by the addition of a little chalk. With pure vinegar, lime forms a limpid solution; but with sulphuric acid, a white insoluble sulphate. Muriate of barytes is a still nicer test. Vinegars are allowed, by the English laws, to contain a little sulphuric acid, but the quantity is frequently exceeded.

Copper is discovered in vinegar by adding more ammonia water than is necessary to saturate it, as a fine blue colour is produced; and lead is discovered by sulphate of soda, hydrosulphurets, sulphuretted hydrogen, and gallic acid, all which throw down a sediment. None of these should produce any change on genuine vinegar.

The excise duty upon vinegar is not calculated by its own specific gravity, but by that of the solution of lime, formed by means of it, as marked by hydrometers, called acetometers. The quantity of carbonate of soda it would require to saturate it, seems a more eligible process, and would tend to discourage the addition of sulphuric acid.

Sugar Vinegar.

Good vinegar may be made from a weak syrup, consisting of ten avoirdupois pounds of sugar to every eight gallons of water. The yeast and rape are to be here used as before described.

This sugar vinegar is usually flavoured with various fruits, one of those most commonly used in gooseberries; twelve pints of bruised gooseberries are generally mixed with the above proportion of sugar and water, put into stone bottles of a moderate size, stopped with a loose cork, merely to keep out the dust, and exposed to the sun, until the vinegar is completed, which generally takes a whole summer.

Whenever the vinegar is considered to be completely made, it ought to be decanted into tight barrels or bottles, and well secured from access of air. Boiling for a few minutes before it is bottled is found favourable to its preservation.

Distilled Vinegar.

Vinegar, obtained by the preceding methods, has more or less of a brown colour, and a peculiar, but rather grateful, smell. By distillation in glass vessels, the colouring matter, which resides in a mucilage, is separated; but the fragrant odour is generally re-placed by a burnt or smoky smell and taste.

The best French wine vinegars, and also some from malt, contain a little alcohol, which comes over early with the watery part, and renders the first product of distillation scarcely heavier, sometimes even less heavy than water. It should accordingly be rejected.

Towards the end of the distillation, the burnt odour and taste increases. Hence, only the intermediate portions are retained as distilled vinegar. The specific gravity varies from 1.005 to 1.015, while that of common vinegar of equal strength, varies from 1.010 to 1.025.

To avoid the burnt smell and taste, the London druggists mix an equal measure of water with the vinegar before distillation, and draw off the original quantity.

Vinegar of Wood, or Pyroligneous Acid.

Vinegar has been long prepared for the calico printers, by subjecting wood in iron retorts to a strong heat. The following arrangement of apparatus has been found to answer well. A series of cast-iron cylinders about four feet diameter, and six feet long, are set in pairs horizontally in brickwork, so that the flame of one fire may play round both. Both ends project a little from the brick-work. One of them has a east-iron plate well fitted and firmly bolted to it, from the centre of which an iron pipe about six inches diameter proceeds, and enters at a right angle the main cooling pipe. The diameter of this main pipe may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by an iron plate smeared round its edge with clay, and secured in its place by wedges. The charge of wood for such cylinder is about 8 cwt.

The hard woods, oak, ash, birch, and beech, are alone used, but fir does not answer. The heat is kept up during the day time, and the furnace is allowed to cool during the night. Next morning the door is opened, the charcoal removed, and a new charge of wood is introduced. The average product of wood vinegar, or raw pyroligneous acid, is thirty-five gallons. It is much contaminated with tar; is of a deep brown colour; and has a sp. gr. of 1·025, so that it weighs about 3 cwt.; but the residuary charcoal is found to weigh no more than one-fifth of the wood employed.

The raw pyroligneous acid is rectified by a second distilla-

tion in a copper still, in the body of which about twenty gallons of viscid tarry matter are left from every hundred of vinegar, and there passes over a transparent, but brown vinegar, having a considerable burnt smell, and its sp. gr. is 1·013. Its acid powers are superior to those of the best wine, or malt vinegar, in the proportion of three to two.

The French now manufacture wood vinegar in a different apparatus, in which the gas yielded by the wood is made to supply a part of the heat necessary for its own distillation.

Fig. 108, represents this apparatus. Wood, well seasoned and dried, is introduced into a large upright cylinder, *a*, made of iron plates rivetted together, and having on the side of its upper part a short cylindrical neck. An iron cover, *b*, is closely fitted to this pot, and then it is lifted by means of a crane and tackle, *c*, and placed in the furnace, *d*, of the same shape as the pot, and the furnace is then covered with a lid, *e*, constructed of brick work. A moderate heat is then applied to the furnace, at first the vapour soon ceases to be transparent, and smoke begins to issue. At this time two adapters are fitted to the cylindrical neck, by whose means the cylinder serving as a body, is connected with the condensing apparatus. This apparatus is different in the various manufactories; in some the condensation is effected by the coolness of the atmosphere, the vapours being made to pass through a long extent of cylinders, and sometimes of casks adapted to each other, but most generally, the condensation or cooling is effected by water, when it can be procured in sufficient quantities.

The most simple apparatus for this purpose consists of two cylinders, *e*, *f*, enclosed one within the other, and having between them a space sufficient to allow a large quantity of water to flow through them, and thus cool the vapour. These cylinders are adapted to the distilling apparatus, and placed inclined to the horizon. To the first double tube, a second, and then a third, is adapted, and placed in a zigzag form, in order to occupy as little space as possible. The water is made to circulate in the following manner: at the lower extremity, *g*, of the condensing apparatus, there is a pipe which ought to be somewhat higher than the highest part of the whole of the condensing apparatus, where, at *h*, there is another pipe bending down towards the ground. The water from a cistern runs through the perpendicular pipe, *g*, to the lower part of the condensing apparatus, and fills all the space between the cylinders, *e*, *f*. When the operation is going on, as the vapours are condensed, they raise the temperature of the water, which becoming more rarified and lighter, ascend to the highest point, and flow out of the curved pipe, *h*, and are replaced by fresh cold water from the cistern.

The condensing apparatus terminates in a brick gutter, *i*, which is constructed under ground. At the end of this gutter is a bent pipe, *K*, which allows the liquid products to flow into a cistern, from whence, when it is full, it discharges itself by means of a syphon into a large reservoir. The pipe which is at the end of the gutter dips into the liquid, and thus cuts off the communication with the interior of the apparatus. The gas, which is disengaging, is conveyed by means of the tube, *i*, *l*, from one of the sides of the gutter, *i*, below the ash-room. This pipe has a cock, *m*, before reaching the furnace, in order to regulate the quantity of gas that may pass, and to cut off the communication at pleasure. That part of the pipe which ends in the ash-room of the furnace, rises perpendicularly some inches, and terminates at *n*, like the nose of a watering pot: by this means the gas is distributed equally under the distilling vessel, without any risk of the pipe being obstructed either by the fuel or the cinders.

[This last-mentioned French apparatus is too refined and complicated for a manufactory of this article on an extensive scale; the condensing part is particularly so; it is a far simpler

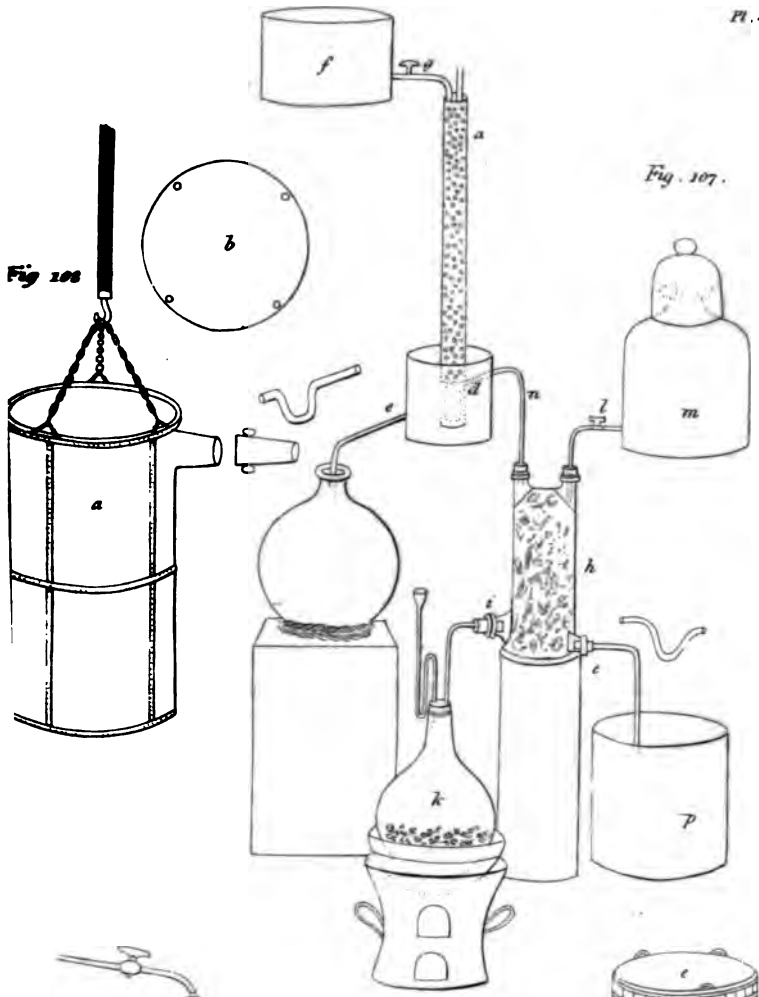
f
g
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Fig. 106
Fig. 107.
d
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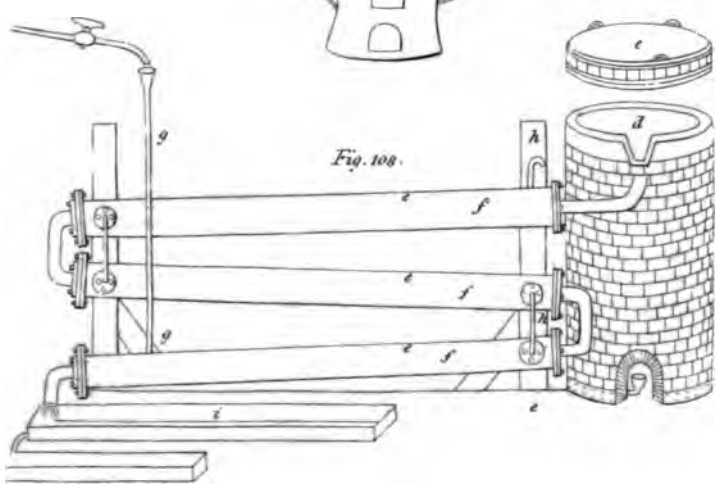
g
Fig. 108.
c
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TILDEN FOUNDATIONS
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and cheaper plan to conduct the tubes through a cistern or refrigerator of cold water. The horizontal cylinder is the best form for the retort. The combustion of the gas is attended with a considerable saving in fuel. I am informed by a manufacturer of this article, that in certain stages of the distillation, it will nearly supersede the use of any other fuel. This arrangement is equally applicable to the horizontal cylinder. The cistern for the reception of the condensed acid should be very large, so as to allow time for the tar to rise before it is drawn off by the syphon, which should take the liquor from about midway from the top to the bottom of the cistern, as a portion of the impurities of the liquid fall to the bottom as well as rise to the surface. Some manufacturers employ a succession of cisterns on different levels, the highest being the first recipient, and draw from one to another so as to allow more time for the tar to rise before the acid is put into casks for the market. The greatest demand for the acid is for the uses of the calico-printers, for whom it should have a specific gravity of 1.035 or 7° on Twedale's hydrometer.]

The heat required is not very considerable, but towards the end of the operation the heat is increased, so as to make the iron cylinders red hot, and the time when the operation is completed is ascertained by the colour of the gas flame. At first it is of a reddish yellow, then it becomes blue, and finally it is quite white, which is a mark that the combustion is carried far enough. There is another mode in which the operator judges of the completion of the process: a few drops of water are let fall on that part of the pipe close to the furnace, which is not surrounded by the second pipe containing water, and when it evaporates without noise the distillation is thought to be finished. The adapting pipes are then separated, and the end of the distilling cylinder is closely stopped by an iron cover, and brick clay. The lid of the furnace is then lifted off, and afterwards the distilling cylinder is taken out and immediately replaced by another which has been prepared in the meantime. When the pot which has been taken out is cold, the charcoal is taken out and the acid is then purified.

A demidecastere of wood (two-thirds of a cubic fathom,) which requires about eight hours' firing, yields about seven voies and a half of charcoal, of about 130 pounds each: and, according to Mollerat, a cubic yard, or about 700 pounds, of wood, yield by distillation 25 gallons of pyroligneous acid, and about 50 to 60 pounds of tar.

Purified Wood Vinegar.

This is also called *crystal vinegar, acidum aceticum fortius;* and *pure pyroligneous acid.*

Acetate of soda, made from rectified pyroligneous acid, and

reduced to the state of very white crystals, is ground and put into a copper pan, and there is added at once a sufficient quantity of oil of vitriol to decompose the acetate by uniting with the soda. The sulphuric acid runs to the bottom of the copper pan, the heat consequent to its action on the acetate is spread on a large mass, and does not rise very high. As the acetate falls in the middle, the laborant rakes down more, and the decomposition thus proceeds as slowly as may be desired. If the oil of vitriol is added gradually, the heat becomes considerable, so as to cause the acetic acid to rise in vapours, which are insupportable by any workmen.

Such part of the new-formed sulphate of soda as separates in crystals is separated by straining off the liquid, which is then distilled in a copper still, observing to reserve apart the latter portions of distilled liquid, as being coloured.

[Another method of procuring a very pure and concentrated vinegar, is, to saturate the redistilled pyroligneous acid with chalk, evaporate the liquid acetate to dryness, and subject it to gentle torrefaction, by which means the tarry and empyreumatic matter is completely dissipated; so that on decomposing the calcareous salt by sulphuric acid, a very pure, colourless, and grateful vinegar rises in distillation. Its strength will be proportioned to the concentration of the decomposing acid. The most difficult part of this operation is to determine the exact point at which the torrefaction is to be stopped; if it be carried too far, the acetic acid will be liable to be decomposed: if not far enough; the empyreumatic matter will not be destroyed; but a little experience will enable the operator to ascertain the necessary points.]

The acid thus obtained is generally sold in France, forty acidimetric degrees strong.

The purified wood vinegar, sold in England for pickling, and other household uses, contains about one-twentieth of its weight of pure acetic acid, and the remainder is water.

The college orders the wood vinegar used by the apothecaries, under the college name of acidum aceticum fortius, to have the specific gravity, 1,046, and that 100 grains should saturate 87 of carbonate of soda, or, in the college language, sodæ subcarbonas.

Notwithstanding Glauber wrote an express treatise upon the usefulness of wood vinegar, yet the general neglect in England of reverberatory furnaces, for distilling with a naked fire, caused his observations to be disregarded. The introduction of iron cylinders for distilling coal gas, led to the general use of Boerhaave's reverberatory furnace, and the manufacture of wood vinegar, by means of which not only the acetates of iron, and of alumine, but also the acetate or sugar of lead, are now manufactered at home, instead of being imported from Holland.

Spirit of Verdigris.

This is also called *radical vinegar*, and is prepared from the distilled verdigris made in wine countries. For this purpose this crystalized acetate of copper, being slightly dried and bruised, is put into a coated glass or stone-ware retort, which may be quite filled up to the bend of the neck. To this retort is to be luted a glass adapter, and at least two or three receivers, to the last of which should be added a bent balled pipe, the farthest end of which dips into a bottle of distilled vinegar.

The apparatus being luted, the receivers being previously placed in vessels of cold water, the distillation may be begun, the heat being augmented gradually until the acid comes over in a string of drops. The vapours give out much heat to the receivers, which causes a necessity of using so many; and when the water in which they are placed grows hot, fresh cold water must be gradually added, and on no account suffered to run on the uncovered part of the receivers, otherwise they would be cracked. The heat is governed by the bubbling of the gas through the distilled vinegar, which ought not to be too quick. At first a colourless liquid comes over, then small pale green crystals appear near the end of the neck of the retort; these afterwards disappear, and colour the liquid collected in the receivers. The operation is finished when the receivers grow cool, and gas no longer passes through the distilled vinegar.

The apparatus must not be undone until the retort is quite cold, as the residuum would take fire if exposed while warm to the air. This residuum, melted with an equal weight of black flux, yields very pure copper.

Twenty kilogrammes ·315, or about 45 avoirdupois pounds of distilled verdigris, yielded nine kilogrammes ·943 of unrectified green acid, 6 kilogrammes ·792 of copper, and 3 kilogrammes ·580 of gas carried off, containing as much acetic acid as saturated ·091 of a kilogramme of very strong potasse water. The green spirit is rectified by distilling it nearly to dryness in a glass retort, changing the receiver when about one-third, being the weakest portion, has come over: the remainder is a very strong acetic acid.

As the acetic acid obtained by this process contains some of the burning spirit of vinegar, of the old chemists, or the pyro-acetic spirit of Chenevix, its smell is very agreeable, and much superior to that of the acetic acid from the alkaline acetates by sulphuric acid: so that it is used as a stimulant in smelling-bottles.

Spirit of Sugar of Lead.

This, like the preceding, can only be properly made from the salt manufactured in wine countries; as the spirit distilled from

either verdigris or sugar of lead manufactured with pyroligneous acid would want that fine smell that is communicated by the pyroacetic spirit, although, when scented with oil of rosemary, or some other strong-scented oil, it will do well enough for the dull organs of scent of the Northern Europeans.

It is obtained from sugar of lead in the same manner as the spirit of verdigris is from distilled verdigris. Wilson, in 1660, added bole to prevent the salt from becoming liquid.

Acetic Acid by Charcoal.

This process was invented by Lowitz. Distilled or even common vinegar is made into a paste with well-burned charcoal powder; and the paste being put into a stone-ware retort, is distilled by a gradual fire. Slightly acidulated water comes over at first, and then the receiving bottle being emptied, the joints well luted, and the heat increased, the acid comes over in a concentrated state, and may be obtained in a glacial or crystalline state.

Crystallized Acetic Acid, from Acetate of Soda.

For experimental purposes dry acetate of soda and sulphuric acid are mixed in the requisite proportions and distilled in a retort: an acetic acid comes over which is so strong that it crystallizes when cooled down to a low temperature, and remains in crystals till the heat rises to 50°. By pouring the liquid portion off the crystals, and drying them on blotting paper, they may be obtained as dry as the crystals of tartaric acid.

These crystals may be melted, by leaving them for 24 hours in a warm room, into a liquid which does not crystallize, though kept for a long time in a temperature as low as 40°; but if it is even raised to the temperature of 45°, and a single crystal of acetic acid flung into it, a number of crystalline spiculæ dart out with rapidity all over the liquid, the temperature rises from 45° to 51°, and by degrees the whole liquid assumes the solid form, and is composed, according to Dr. Thomson, of one atom or charge of acetic acid united with one of water.

By dissolving given weights of the crystals of pure acetic acid in water, and examining their specific gravity at 60°, that professor found that an atom of acid, united with different numbers of atoms of water, had the undernoted specific gravities:—

Atoms of water.	*Specific gravity.*
1	1·06296
2	1·07060
3	1·07084
4	1·07134
5	1·06320
6	1·06708
7	1·06349
8	1·05974
9	1·05794
10	1·05439

Dr. Thomson remarks, that the specific gravity of the liquid is at a maximum when it consists of one atom of acid united to four atoms of water, and of course it follows that knowing the specific gravity of acetic acid is not sufficient to determine its strength.

100 acetic acid is composed, according to Berzelius, of 47 of carbone, 46·79 of oxygen, and 6·21 of hydrogen, or $H^6 C^4 O^3$, and its number is 641·120: Dr. Thomson corrects Berzelius' deductions, and makes the acid equal to $C^4 O^3 H^2$, or 6,250.

BORACIC ACID,

Originally known by the medical name of *Homberg's sedative salt of vitriol*, or by contraction, of *sedative salt* only.

The easiest method of procuring boracic acid is by dissolving borax in hot water, filtering the solution, then adding sulphuric acid by little and little, till the liquid has a sensibly acid taste; and laying it aside to cool. A great number of small laminated crystals will form, which are the boracic acid. They are to be washed with cold water and drained upon brown paper. To extract the whole of the boracic acid, the solution should be evaporated after the first crop of crystals are obtained. When concentrated and set aside, an additional quantity of boracic acid falls down.

Boracic acid, thus procured, is in the form of thin hexagonal scales; of a silvery whiteness, having some resemblance to spermaceti, and the same kind of greasy feel, owing most probably to the remains of the acid employed in procuring it; and is but little used, for soldering metals.

Boracic acid has lately been found native, in Italy, in large quantities, both in a solid state, and forming an ingredient in the water of some lakes; and this has been brought into the market in such quantities, and at so low a price, that it has been used to make borax, by being united with soda.

According to Berzelius, dry boracic acid is $B^{\cdot\cdot}$, or 269,650; and the crystals, $B^{\cdot\cdot} + 2(H{\cdot}H,)$ or 496,180; but Dr. Thomson makes the atomic weight 5,250.

CARBONIC ACID.

Scarcely any substance has had more names given it by theorists. It has been called *gas of wine*, *choke damp*, *cretaceous air*, *acidulous gas*, *aerial acid*, and by the present theorists *carbonic acid gas*, to which is usually added, in popular works, the name of *fixed air*, as an explanatory synonyme.

It is met with in the bottoms of mines left unworked, in old dried up wells, in cellars, or in pits which have not been opened for some time, and in brewers' and distillers' working tuns, on the surface of the liquor. Its presence is shown by its instantly drowning men and animals that, deceived by its being invisible; venture into it, by instantly extinguishing the flame of a candle; and by the smoke of a newly-blown out candle floating upon it as oil on water.

Carbonic acid gas, or fixed air, may be made by dissolving limestone in weak sulphuric or muriatic acid, and receiving the gas in bottles or jars in a water trough. It has been proposed

to fill up bottles with it, in order to preserve fruit, and even animal flesh, but they contract a musty flavour in it.

Carbonic acid gas is considered by the Lavoisierian theorists as C., hence Berzelius makes its weight, 275,330; which Thomson corrects to 2,750: the Stahlians would regard it as C Aq^{n} O; or three by weight of the carbonaceous element with eight of water, and an indeterminable quantity of that principle that forms oxygen gas with water.

Carbonic Acid Water.

This acidulous drink has been known for some time by the name of *water impregnated with fixed air.*

When it first came into use, a number of apparatus were contrived for the speedy impregnation of the water; some of which are still in being, although seldom used, as the manufacturers supply a better article than can be made by private persons, and at a very cheap rate.

When a person lives near a brewery or distillery, a small quantity of carbonic acid water may be made occasionally by holding a flat dish of newly-boiled water a little above the surface of the liquor fermenting in the working tun; the water quickly absorbs its own measure of the carbonic acid gas or choke damp that is discharged from the fermenting liquid.

Carbonic acid water may also be made by putting pieces of marble or limestone into a retort, or gas bottle, adding very weak sulphuric acid, and receiving the carbonic acid in bottles, standing in the water-trough till they are half full; then shaking the bottles to promote the absorption of the gas. Or the water may be put into the receivers of Hassenfratz's distilling apparatus, p. 200, fig. 85, or any similar apparatus: and the gas ejected from marble or limestone sent through it.

Welter has proposed a very ingenious apparatus, which is not only applicable to the making of carbonic acid water, but also to the preparation of the super carbonates of the alkalies, and many other operations.

This apparatus is represented in fig. 109. The vessel, *e*, provided with three openings, one below and two above, is filled with marble broken into pieces. Bent pipes, 1, 2, 3, are luted to these openings. 1, is to carry the carbonic acid gas to the bottom of a tub or wide stone jar, *a*, filled with the water or other liquid to be impregnated. 2, is to convey the muriatic acid to the marble by a fine opening at the end; 3, is bent, and placed so as to carry off the solution of lime in the muriatic acid as soon as it reaches a certain height, and let it drip into the basin, *k*.

a, *b*, *c*, *h*, is the tub, or stone jar, for holding the water or liquid to be impregnated, and is nearly similar to that of M. Berthollet, for procuring oxymuriatic acid, but without the agitators, although these might be used. Muriatic acid, weakened with an equal quantity of water, is first poured into the bent pipe, 2, from whence it flows into *e*, and immediately disengages a portion of the carbonic acid gas from the marble, which passes into the inverted dishes, *b*, *c*; when this gas ceases to be absorbed, the muriatic acid ceases also to pass over, and stands

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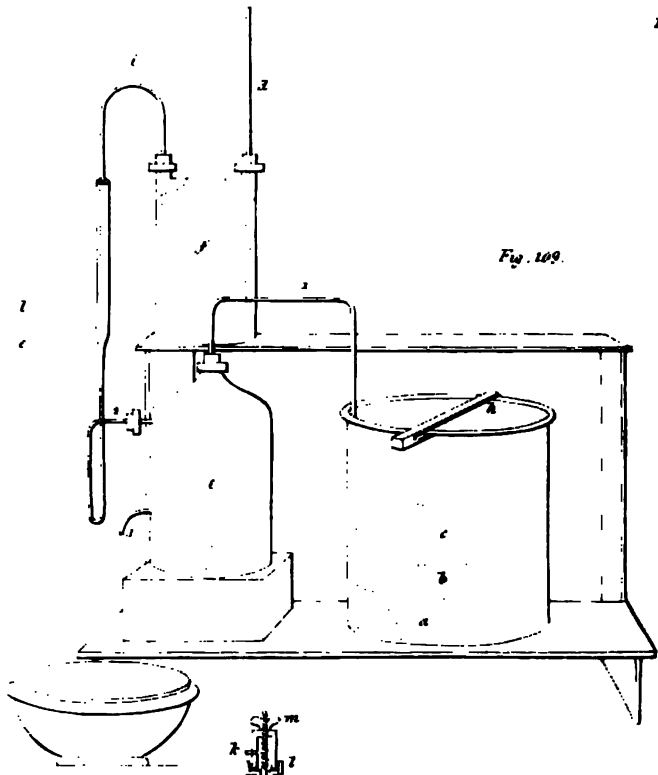

Fig. 109.

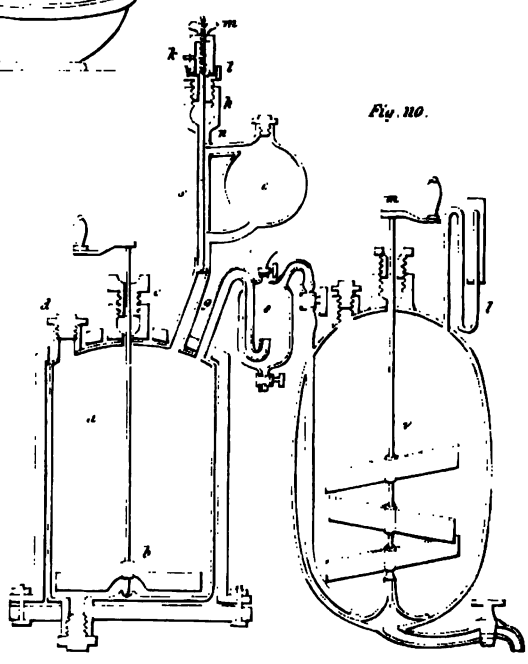

Fig. 110.

at a certain height in the bent pipe, 2, proportioned to the pressure of the water on the opening at *a*, say at *l*.

Now, in order to feed this apparatus with muriatic acid, as the water in the tub absorbs the carbonic acid gas, *f*, is a bottle with two openings, or a single wide mouth closed with a bung, with two openings. Into one of these openings, a straight cane, *d*, is luted, and into the other a simple syphon, *i*, after the bottle has been nearly filled with weak muriatic acid. The leg of the syphon, *i*, is introduced into the pipe, 2. The lower end of the cane, *d*, ought to be lower than the level, *l*, of the liquid in 2, and higher than the lowest end, *e*, of the syphon. On blowing into the cane, *d*, the muriatic acid is forced over the arch of the syphon, and flows into the pipe, 2. As the water in the tub, *a*, absorbs the gas, the muriatic acid running into the vessel, *e*, by the bent pipe, 2, brings over more muriatic acid from *f*, and when the acid in this pipe, 2, falls below the level of the lower end of *d*, as at *m*, a bubble of air passes by this pipe, and a similar quantity of acid runs through the syphon, and again from the bent pipe, 2, upon the marble in *e*, according as the carbonic acid is absorbed by the water in the tub.

This apparatus is said to work very regularly, and is certainly a useful method for causing the absorption of gases, as it continues to act till the materials are exhausted, or saturated. If the tub, or stone jar, *a*, *h*, is covered, and a cock fitted at the bottom, fresh water may be added as the already impregnated water is drawn off for use. The nature of the apparatus, however, does not allow a great pressure to be given to the gas, and hence, the water does not absorb much more than its own measure of carbonic acid gas.

But when it is required to impregnate the water with a greater quantity of carbonic acid, an apparatus must be used which will allow of considerable resistance being made to the the escape of the gas; and by this means each measure of water may be made to absorb about two measures and a half of the carbonic acid gas.

Fig. 110, represents an apparatus designed to impregnate water, with carbonic acid gas, formerly called fixed air; it is composed of the following parts.

The generator, *a*, is made of cast-iron, three quarters of an inch thick; and to prevent the sulphuric acid from acting upon it, the whole is lined with sheet lead, of about nine pounds to the square foot. This vessel contains about fifteen gallons, and has a stirrer, *b*, also lined with sheet lead, and which works on a pivot at the bottom: this pivot passing through the stuffing box, *c*, at the top of the vessel.

The vessel is filled up to the dotted line with a mixture of whiting and water, which is introduced by the opening at *d*.

The acid holder, *e*, contains two gallons, and is filled with oil of vitriol up to the dotted line. This acid holder is formed of lead, three quarters of an inch thick.

The acid is kept from running down into the generator by means of the conical lead plug, *f*, which fits into a conical opening in the leaden pipe, *g*. This plug is attached to a rod, which moves up and down through the stuffing box, *k*. As it is desirable to prevent the plug from friction, and merely to lift it out of the opening, *g*, or push it into the opening, the rod of the plug is prevented from turning round by means of a pin, *k*, moving in a slit of the bridle, *l*, and the screw nut, *m*, is rivetted loose into the top of the bridle. This kind of plug cock is more complicated than the common cock, but that would not answer where a great resistance to escape is necessary.

The pipe, *n*, which forms a communication between the top of the acid holder, *e*, and the pipe, *s*, in which the plug rod moves, preserves an equilibrium

of pressure, so as to prevent the acid from rising higher in the pipe, *s*, than the level of the acid in the acid holder: by which means, the brass work of the stuffing box is preserved from injury.

To prevent any of the sulphuric acid from being carried over by the effervescence, an intermediate vessel, *o*, containing about three gallons, is formed either of thick sheet lead, or of cast-iron, lined with lead. This intermediate vessel is filled with water up to the dotted line.

The impregnator, *v*, should contain about sixteen gallons. As to its materials, it may be made either of copper, tinned, or of cast-iron, lined with thin sheet lead; and the mill, may either be of tinned copper or of maple wood, which last, giving no taste to the water, is, perhaps, preferable. This impregnator is filled up to the dotted line with water, to which, in making saline waters, the proper proportion of sesqui-carbonate of soda, carbonate of magnesia, or other ingredient, *m*, is to be added.

A pressure gauge, *t*, of quicksilver, is to be placed at a little distance, and connected by means of a leaden pipe: but in the annexed figure, it is represented, for the sake of room, as placed on the top of the vessel.

Nothing can be more simple than the operation of this apparatus. The nut, *m*, being turned, the plug is raised, the oil of vitriol is allowed to run down into the generator, *a*, where it acts upon the whiting, and disengages the carbonic acid gas, in proportion to the quantity of the oil of vitriol that is allowed to run down at once. The nut, *m*, being turned the other way, lowers the plug, and thus stopping the descent of the sulphuric acid, the disengagement of the gas is regulated, and too great an effervescence is prevented. The gas that is disengaged passes through the intermediate vessel, into the impregnator, *v*, where it is absorbed by the water.

The water thus impregnated with the carbonic acid gas in close vessels, which offer great resistance to its escape, is then drawn off into strong half-pint bottles, by means of a cock, which descends to the bottom of the bottle, and immediately corked, and either wired, or the corks tied down.

Some persons use mechanical means to force the carbonic acid gas into water, by means of a transferring pump, or syringe, which is connected at one end with the bladder, or other reservoir of the gas; and at the other with a vessel, or single bottle of water. When the pump is worked, the gas is extracted from the bladder, transferred and forced into the water.

FLUORIC ACID.

The fluor acid is procured from a saline stone, known by the name of fusible spar, fluor spar, false amethyst, &c. It was confounded with spar, till the miners, in consequence of their practice, distinguished it by its useful property of serving as a flux to the most refractory ores.

Marggraf was the first who examined fusible spar, and selenitic spar. He determined their different characters, and that an earthy sublimate may yield in distilling this spar with oil of vitriol.

Priestley first observed, that an acid gas was disengaged in the distillation of this spar with sulphuric acid, which communicated to water, as soon as it came into contact with it, a strong acidity, and covered the surface of the water with a stony crust.

Scheele, in 1771, assigned it the rank it was entitled to among the mineral acids.

When the fluor acid is obtained from a mixture of fluor spar and sulphuric acid in a glass retort, it is rendered impure; for it is saturated with the silica it has dissolved from the retort, and it is mixed with sulphuric and sulphurous acids. The presence of these is immediately shown by the acetate of barytes. To obtain the pure fluor acid, the mixture must be distilled in lead or tin vessels, and the inside of the receiver lined with a coat of wax.

The distillation of a mixture of four ounces of fluor spar, and twelve ounces of sulphuric acid, in this way, is sufficient to render eight ounces of water very strongly acid. The acetate of barytes does not then discover any mixture of sulphuric acid, though the acid obtained by the distillation is strong enough to dissolve calcareous earth with effervescence.

This acid must be kept in flint-glass bottles, coated internally with a mixture of wax and oil.

The acid, when obtained this way, is, however, not quite pure. It is mixed with a small quantity of oxide of lead or of tin, according to the retort made use of.

Two ounces of vitriolic acid, and half an ounce of fluor spar, were distilled in a small retort of lead, in a water bath. The retort weighed eleven ounces eight drams. In the first distillation, it lost one dram and a half; in the second, one dram; and in the third, fifty-eight grains. The acid obtained was whitish, and had a strong smell of liver of sulphur. The fluor acid alone cannot dissolve tin or lead; but during the distillation, the superabundant sulphuric acid dissolve the metal, which is taken from it by the fluor acids, and deprived of its oxygen. In this distillation, the heat of boiling water must not be exceeded, because the sulphuric and sulphurous acids would, in that case, pass into the receiver with the fluor acid.

The quality which the fluoric acid possesses of dissolving glass, and those silicious stones which resist the action of most solvents, is applicable to use.

M. Puymaurin put a small piece of diamond into the fluor acid, in a glass vessel, and heated the vessel two or three times in a sand heat; after the diamond had been four or five days in the acid it disappeared, and nothing could be observed in its place but some small shining particles, which rolled about at the bottom of the vessel, if it was at all agitated.

This experiment was repeated upon two other diamonds. These two did not appear to suffer the smallest alteration. If this experiment had not been repeated, it might have been supposed that the fluor acid was a solvent for diamonds.

M. Puymaurin also exposed various gems, and other silicious substances to the action of this acid.

It is by no means indifferent in what vessels the pieces of stone or gems to be examined are placed. The glass vessels M. Puymaurin first made use of were not so proper for the purpose as he wished. The internal surface of the vessels was corroded, a gray gelatinous substance covered the pieces of stone, and they were found little or not at all acted upon by the acid.

Vessels of box wood, although varnished, could not resist the gentle heat necessary to hasten the action of the acid; it soon penetrated through the pores in such a manner that it was necessary to procure vessels of another kind.

Vessels of pewter have all the advantages wished; but heat must be applied very gradually, because the acid becomes volatile with a very gentle heat, and the vessels, when empty, are apt to melt. It is also necessary to be very particular respecting the purity of the fluor acid; if it is mixed with sulphuric acid, this last attacks and calcines the metal of the vessels, and the fluor acid then exerts its action upon these calces or oxides, and becomes loaded with them.

M. Puymaurin exposed among several others, the following substances in pewter vessels, with a sufficient quantity of fluor acid to cover them, to a moderate heat, for the space of two days.

	Weight in grain.	Loss of weight.
The kind of jaspar called blood-stone,	8½	1½
Striped agate,	6	1
True aventurine, but of inferior quality,	4½	1½

The striped agate lost its transparency and its fine red colour.

The aventurine appeared only like a piece of a gray pebble, and its brilliant particles had entirely disappeared.

The blood-stone suffered the greatest change: the beautiful broad red spots, from which it takes its name, were changed into spots of a brownish red colour; the dark green was changed into a grayish colour, and the hardness of the stone was so diminished that it might be scraped with a knife. It had also become very brittle; when broke, the broken part appeared of a dark brownish green colour.

Since he made these experiments, M. Puymaurin has engraved various characters upon blood-stone, and upon agate, by means of the fluor acid.

A small hexaedral crystal lost its polish, but did not decrease

in weight. Four small garnets lost a portion of their weight, and became of a beautiful dark rose colour; the outer surface having been taken off by the acid. Gypsum from Montmartre, and sand-stone from Fontainbleau, were completely dissolved.

A large series of experiments have been also made by Mr. Kortum.

Fluor acid acts more readily upon glass than upon rock-crystal. The silicious earth in glass is divided by fusion, and by its mixture with alkaline substances; and, consequently, presents a multitude of surfaces to the action of the acid, which soon destroys it; reducing it into a light powder, of a shining white colour, and which may be again fused by being mixed with an alkali.

The fluor acid has almost as much action upon glass as aqua fortis and other acids have upon copper, or other metals: and it has been applied to the engraving upon plates of glass. Although pewter or molten lead vessels may be used, yet it will be found advantageous to use a small silver alembic, holding about a pint, and receiving bottle for the distillation: two ounces of the spar, with four ounces of oil of vitriol, will yield about an ounce of very strong fluoric acid, requiring the admixture of three or four ounces of water to render it proper for engraving. The fumes of the acid must be anxiously avoided, and the hands guarded with very thick gloves, as the burns produced by the least quantity of the acid, gives the most excruciating pain, or rather tortures.

The nature of fluoric acid is still disputed amongst theoretical chemists; and several different opinions are held by them on the subject.

According to Berzelius, the acidum fluoricum is a compound of a hypothetical principle, fluoricum, with two charges of oxygen, or $F\dot{}$, and its number 275,030.

According to Sir H. Davy, and M. Ampére, fluoric acid is a hydro acid, composed of one atom of a hypothetical principle, called fluorine, equal to 2,250, and one of hydrogen, or 125, so that the charge of the acid is 2,375.

According to Dr. Ure, fluoric acid is a hitherto undecomposed body, and consequently may be esteemed as a principle. He agrees with Sir H. Davy in making its equivalent number 2,375.

The fluoric acid is such a disagreeable subject to meddle with, that chemists are not fond of making experiments upon it.

CITRIC ACID.

The citric acid is that which gives their acid taste to lemons, citrons, limes, and many similar fruits. The acid has several uses in the arts, which renders its proper preparation an object of great importance in manufacturing chemistry. Like the oxalic acid, it possesses the property of speedily dissolving the oxides of iron, which causes linen to be, as it is called, iron moulded; and hence is used by housewives for the purpose of getting rid of these spots. The dyers make still more use of

it, for no other acid can be employed with such success in enlivening the colours given by safflower: it appears also that it will form with grain tin a liquor which with cochineal, produces scarlet colour superior to the usual dye, especially with silk, and morocco leather. Citric acid whitens and hardens tallow, but as tartaric acid acts nearly as well in this respect, and is considerably cheaper, it is seldom employed for this purpose.

The fruits from which it is procurable, not growing in the countries where the citric acid is most in use; there is a necessity for finding some method of transporting the juice, or some preliminary preparation of it, previous to the manufacture of citric acid.

Citron juice is still exported in large casks from Italy to Germany, and the north of Europe, and was formerly to England, when it was an article of the materia medica, used in the Pharmacopœia under the name of acetositas citri: the juice thus kept deposites much foot, from which foot, when the acid liquor has been drawn off, a species of essence of lemons is distilled; the clear liquor racked off may be kept for a long time, especially if covered with a little sweet oil, and stored in a cool cellar.

Georgius, of St. Petersburgh, attempted to render the juices of these fruits fit for keeping, by exposure of them to cold, but this process is evidently impracticable in those warm climates, where the fruits grow in the open air.

The West Indians are in the habit of adding rum to the juice of limes, a small species of lemon, with a view of allowing it to be transported to Europe: but this addition prevents the juice from being used for the manufacture of citric acid, and it can only be employed for making shrub or other liqueurs.

Scheele having shown the method of making this acid in a pure state, by adding chalk to the juice, and then decomposing the citrate of lime thus formed, by abstracting the lime by means of a sulphuric acid; the addition of chalk to the juice has been used as a means of transporting the material for citric acid rather than the juice itself.

If the juice is freshly expressed, it should stand for some little time to allow the mucilage to settle, which would otherwise mix with the citrate of lime, and, becoming black on the addition of the sulphuric acid, would render the purification of the citric acid difficult.

When the acid is bought, as is usual in Italy, of the farmers in the neighbourhood, it is necessary to examine its strength and purity. The specific gravity of good citron juice is from 1·0312 to 1·0625; the degree of sourness may next be determined by adding to a certain quantity of it the necessary quantity of crystallized, but not powdery, carbonate of soda, to saturate it. The larger quantity of salt of soda it requires, the

stronger is the acidity of the juice. Lest, however, other cheaper acids may be added to increase its apparent strength, some test liquors may be added to separate portions of the juice after it has been filtered through paper. The addition of nitrate of barytes will show if any oil of vitriol has been added, by producing a sediment; a solution of silver in a nitric acid will, by the same means, show if spirit of salt has been added. To detect the addition of aqua fortis, or any other nitric acid, or of vinegar, requires farther research: some of the suspected juice, and also some of known purity, must be saturated, adding chalk until no farther frothing takes place, and when the sediment is fallen down, the specific gravity of the supernatant liquor must be examined; for if any nitrate of lime, or acetate of lime be now present, it will render the mother water of the adulterated juice heavier than the pure.

The purity of bought juice being thus ascertained, it may be converted into citrate of lime for exportation, by stirring it continually while a sufficient quantity of powdered chalk or whiting is added to saturate it, of which it generally takes about one-sixth of its own weight; and then letting it settle until it is clear, the liquid is poured off, and boiling water poured on the sediment, and the whole being well stirred up, it is left to settle, and then poured off; this washing is repeated until the water comes off clear; when this purified sediment, or citrate of lime, is to be dried by exposure to the air and sun.

From this citrate of lime, either fresh, or dry as imported, the citric acid is easily obtained by the addition of oil of vitriol, weakened with four times its weight of water, for fresh moist citrate, or with at least six times for dry citrate. If fresh citrate is used, it will take about nine pounds of oil of vitriol for every ten pounds of chalk or whiting that was used in preparing it: the dry citrate will require about 45 pounds of oil of vitriol to each 100 pounds.

The acid and water being mixed together, are to be poured gradually upon the citrate of lime, and the whole kept constantly stirred; towards the end the mixture becomes more liquid than before, and the sulphate of lime appears to separate from the liquor in crystalline grains. When the whole of the acid is added, the mixture is left for some hours, but is stirred occasionally, and is afterwards assayed, whether too much or too little sulphuric acid has been added. For this purpose, some of the liquor is filtered, and either a solution of nitrate of barytes, or of sugar of lead, in water, is to be dropped into it as long as any sediment falls down, which being separated, is to be itself tried with a nitric acid, diluted with two or three times as much water: if the sediment dissolves entirely

to the nitric acid, the operation has succeeded; but if not, there is an excess of oil of vitriol; if this is but little, the mixture may be heated, which may perhaps, occasion it to unite with some particles of the citrate of lime which has escaped decomposition, and the mixture again assayed; but if the excess of the sulphuric acid is considerable, more citrate of lime must be added, until, on trial, it appears that the whole of the selenite produced is re-dissolved in the nitric acid.

This point being arrived at, there only remains to strain the mixture, to wash out the remains with cold water, to mix these liquors, and to evaporate them for the purpose of crystallizing. The evaporation is first performed in a leaden boiler, until about four parts in five of the liquor have exhaled: it should then be removed to a stone-ware or pewter vessel, set in a copper of water, that the heat may be better regulated than by an open fire. The steaming away of the superfluous water should be stopped occasionally, and a little weak sulphuric acid added to decompose any citrate of lime which may have been dissolved in the acid itself, and the liquor filtered from the sulphate of lime thus separated: for a very small quantity of citrate of lime will impede the formation of crystals, but a slight excess of sulphuric acid is not injurious. The evaporation is to be carried on carefully until the liquor is nearly covered with a skin of fine crystals, when the liquor is to be left to cool. The first crop of crystals is usually dark brown; but if the citrate of lime has been well washed, of a pale brown: by dissolving them two or three times in as little water as possible, straining the solution through a skin of wash-leather, and re-crystallizing, they become white.

The black mother liquor, left after the crystallization, is often flung away, but considering the high price of citric acid, it is best to mix it with ten or twelve times as much water, and then treat it in all respects as though the mixture was fresh citron juice.

Citric acid is sold both in the brown and white state, but at different prices.

Citric acid is considered, by Berzelius, as a combination of four volumes each of hydrogen, carbone, and oxygen, or $H^4\ C^4\ O^4$; and its weight 727,850: Dr. Thomson deducts two atoms of hydrogen, and makes it $H^2\ C^4\ O^4$, and its weight 7,250.

The crystallized acid is made by Berzelius, $H^3\ C^3\ O^3 + HH$· equal to 659,160; and, when, dried, $H^6\ C^6\ O^6 + HH$· equal to 1,205,050: Dr. Thomson considers the dry state as merely a bi-hydrate, and equal to 9,500.

Lime Juice.

This is an impure citric acid, prepared for medical use, as a preventive of the scurvy in sea voyages.

The following method of preserving lime juice in the East Indies, is given in the Calcutta Gazettes of September, 1805:—The limes come in between the latter end of October and the middle of November; and, as they arrive successively in the market, the juice is to be squeezed into earthen vessels holding

about fifteen gallons, and in the evening poured into large casks or pipes, from which rum, brandy, or Madeira, has been lately taken out. But, before the juice be poured out of the earthen pans into these casks into which it is to be collected for purification, a red-hot iron bar, about eight inches long, four inches broad, and two inches thick, having an iron chain fixed to it by a hook, is twice quenched in it, turning it equally round on all sides. When the cask, in which the juice is collected in this manner, is nearly full, there is put into every maund, or ten gallons of juice, half a gallon of Bengal rum, full-proof, and it will then settle and clarify itself by the beginning of December, when it may be drawn off for use, either into small casks or bottles.

TARTARIC ACID.

The process employed at present for obtaining tartaric acid, is that proposed by Scheele in 1770: argol, or crude tartar is to be dissolved in boiling water, and powdered chalk is added to the solution until the effervescence ceases, and the liquid does not redden syrup of violets, or paper stained with litmus or scrapings of radishes. The liquid is cooled and passed through a filter. A quantity of insoluble white powder remains upon the filter, which is the tartarate of lime.

This tartarate must be first well washed, and then mixed with a quantity of oil of vitriol, equal to the weight of the chalk employed (which must have been diluted the day before with water, in the proportion of a gallon of water to each pound of acid,) and the whole well stirred together.

The sulphuric acid uniting with the lime displaces the tartaric acid, and the latter dissolves in the liquid part, which is to be decanted off, and tryed whether it contains any sulphuric acid. This is done by dropping into a small portion of it a little sugar of lead water, as the sediment that will fall down is not dissolvable in acetic acid, if it contains sulphuric acid; but is dissolved if it consists only of tartarate of lead. In the case of the liquid containing sulphuric acid, it must be digested on some more tartarate of lime; if not, it is to be slowly evaporated with a gentle heat, and crystals of tartaric acid, to the amount of about one-third part of the weight of the tartar employed, will be obtained.

Lime has been substituted by Vauquelin for chalk in this process. About 40 parts of slaked lime decompose 100 of argol, or crude tartar, completely; whereas, by Scheele's method, it is only the excess of acid that combines with the chalk.

But when lime is used, the whole tartarate of lime does not separate at once, as a considerable portion is retained in solution by the potasse of the argol or crude tartar. The liquid is, therefore, to be evaporated to dryness and gently heated; and then, by lixiviating the mass, and evaporating the water used to wash it, potasse will be obtained in a state of considerable purity; and the washed tartarate may be added to the

main quantity, or acted upon separately by weak sulphuric acid, as the other portion.

With the same view of separating all the tartaric acid from the argol, Thenard, after saturating the solution of argol with chalk, in Scheele's method, adds solution of chalk in muriatic acid, until it no longer causes a sediment to separate; and thus operates the entire decomposition of the argol, or bi-tartarate of potasse.

Tartaric acid is also preparable by dissolving four pounds of argol in three gallons of water, and adding, gradually, one pound of oil of vitriol. The liquor must be evaporated to one half, and then filtered to separate the sulphate of potasse. The evaporation is then continued, and the liquor filtered from time to time to separate the sulphate: the evaporation is continued to a syrup, and thus about two pounds of crystallized tartaric acid may be obtained.

Tartaric acid is used by the calico-printers to discharge false prints, by candle melters to whiten tallow; it is also used to make lemonade, as being cheaper than the citric acid.

According to Berzelius, dry tartaric acid is composed of $H^5\ C^4\ O^5$ and its atomic weight is 834,490; that of the tartras hydricus, or crystals of tartaric acid, 947,760: Dr. Thomson states the dry acid as $H^2\ C^4\ O^5$ or 8,250, and the crystals, holding a single atom of water, 9,375.

OXALIC ACID.

Oxalic acid is seldom prepared expressly, because it is procured in the manufacture of several other substances, so that it is not economical to prepare it expressly. The following, however, are two modes of preparing it.

To twenty-four pounds of starch, divided among several tubulated retorts, and all placed in one common sand-bath, is added seventy-two pounds of common nitric acid. After a short time the starch begins to dissolve, decomposition takes place, and nitrous gas is evolved. When this action has ceased, twenty-four pounds more of nitrous acid is added, and a slight degree of heat applied until all action has ceased. The liquid is then poured off into earthen pans to crystallize. About five pounds of oxalic acid is obtained. To the mother waters twenty-four pounds of nitric acid is afterwards added, at different times, which gives about two pounds and a half more crystals. This is repeated a third and a fourth time, and their whole produce of oxalic acid is nearly equal to half the starch employed. Oxalic acid is purified by dissolving and re-crystallizing it to separate the nitric acid.

The other mode is this:—To any quantity of nitric acid add molasses, gradually, in the proportion of one pound of molasses to six of the acid employed. A gentle heat is to be applied to the mixture, and nitrous oxide escapes in abundance.

When the molasses is entirely dissolved, distil off part of the acid till the whole has a thick syrupy consistence, and on cooling this will be found to crystallize; the crystals being oxalic acid, nearly equal in weight to half the quantity of molasses employed. The crystals must be dissolved and re-crystallized.

Oxalic acid has also been obtained by distilling nitric acid upon wool.

Oxalic acid, dissolved in water, is employed by calico-printers to destroy or lighten colours which are produced by iron. It is also used in domestic economy, to remove iron moulds, and to take out spots of ink from furniture, or instruments, which it does with the greatest facility. The analytical chemists use it as a test liquor to discover the presence of lime in mineral waters, as it separates that earth from all other acids, and forms with it a solid body little soluble in water, and hence falling down in the form of a white powder. It is also popularly employed to cleanse boot tops, and as its crystals have a considerable resemblance to those of Epsom salt, which is also in popular use as a purgative, several unfortunate accidents have happened through its being taken by mistake, as the corrosive power of this acid is very great, when taken in the same dose as Epsom salt.

Oxalic acid was thought by Berzelius to contain hydrogen even in its dry state, but he has since ascertained that this is not the case: its composition on the Lavoisierian hypothesis is $C^2 O^3$; and its atomic weight, by Thomson, is, of course, 4,500.

BENZOIC ACID.

Benzoic acid was described as long ago as 1608, by Blaise de Vigenere, in his treatise on fire and salt, under the name of *Flowers of Benzoin*, because it was obtained by sublimation; but is now denominated benzoic acid.

The usual method of obtaining this acid is to put a quantity of benzoin, coarsely powdered, into an earthen pot, to cover the mouth of the pot with a cornet of brown paper, and then to apply a very moderate heat. The benzoic acid is sublimed, and attaches itself to the paper. Some use a large house, as it is called, made of pasteboard and laths, and lined with blotting paper, in loose sheets, every time it is used. Some empyreumatic oil is generally carried up, which soils and injures the acid sublimed.

Newman proposed moistening the benzoin with alcohol, and distilling it in a retort with a low heat. The acid comes over immediately after the alcohol, partly in crystals, and partly of the consistence of butter.

Scheele, in 1775, published a different method, which is often used at present. A gallon of water is poured upon four pounds of unslaked lime: and after the ebullition is over, nine more gallons of water are added. Then twelve pounds of finely pounded benzoin are put into a tinned copper boiler, and six pounds of the above milk of lime are first put upon it. They are mixed well together, and thus successively the rest of the mixture of lime and water is added. If it were poured in

all at once, the benzoin, instead of mixing with it, would grow lumpy. This mixture ought to be boiled over a gentle fire for half an hour, and constantly stirred, then suffered to stand quiet for an hour, in order that it may settle. The supernatant limpid liquor is poured off into a stone-ware vessel. Upon the remainder in the pan ten more gallons of water are poured; they are boiled together for half an hour, then taken from the fire, and left to settle. The supernatant liquor is added to the former; and upon the residuum some more water is poured: it is boiled as aforesaid, and the same process is repeated once more. All the residuums are at last put upon a filter, and hot water several times poured upon them. All these clear yellow liquors and decoctions are mixed together, and boiled down to two gallons and a half, which are then to be strained into another glass vessel.

After they are grown cold, muriatic acid is to be added, and constantly stirred, till there be no farther precipitation, or till the liquid tastes a little sourish. The benzoic acid, which was before held in solution by the lime, falls down in the form of a fine powder.

Mr. Hatchett has observed, that on digesting benzoin in sulphuric acid, a great quantity of beautifully crystallized benzoic acid is sublimed. This process is the simplest of all, and yields the acid in a state of purity; it claims, therefore, the attention of manufacturers.

Benzoic acid is also obtainable in large quantities from the urine of grass-eating animals, as horses, or cows; by merely boiling it down to a small quantity, and then adding muriatic acid; the benzoic acid separates and falls to the bottom of the liquid. It may also be obtained by adding muriatic acid to the water that drains from dunghills. The acid thus prepared has not the fine scent of that procured from benzoin; but this scent may be given it by subliming it with three quarters of an ounce of benzoin to the pound.

Benzoic acid is not used, except in making the popular medicine, paregoric elixir; and in a few articles of perfumery.

The crystals of benzoic acid contain no water, and are estimated by Berzelius to be composed of H^{12} C^{15} O^{3} equal to 1,509,550. Dr. Thomson considers them as H^{6} C^{15} O^{3} equal to 1,500, which is in effect the same, H^{2} of Berzelius, being, as has been shown in p. 352, H of Dr. Thomson.

GALLIC ACID.

This acid may be obtained by nut-galls; by merely infusing them in water, and straining the infusion, and setting it by till it has dried up: the sides of the vessel, and the under surface of the dry mass, will be found covered with small yellowish crystals of gallic acid, which may be purified by solution in

spirit of wine, and distilling to dryness. This, the process of Scheele, is simple but tedious.

Friedler orders an ounce of galls to be boiled in a wine pint of water, to a half: add to this the sediment (previously well washed) produced by adding carbonate of potasse water to a solution of two ounces of alum in water. The next day filter off the liquid, and run warm water through the sediment till the liquid no longer renders copperas water black: on evaporating the liquid, fine needle-like crystals of gallic acid will be obtained.

Barruel advised Thenard to mix a solution of white of egg with the infusion of nut-galls, until the infusion ceases to become clouded, to filter the liquid, evaporate to dryness, dissolve the dry mass in spirit of wine, again filter, and distil off the spirit to the proper degree for the formation of gallic acid.

Gallic acid is used as a test liquor for iron, in analytical chemistry; for washing over decayed writings to restore their legibility; and scarcely for any other purpose.

Gallic acid, according to Berzelius, is $H^6 C^6 O^3$ equal to 791,780. Dr. Thomson has not thought it worth his attention in his late work.

SUCCINIC ACID.

When amber is distilled a volatile salt is obtained, which is mentioned by Agricola under the name of *salt of amber;* but its nature was long unknown. Boyle was the first who discovered that it was an acid. From succinum, the Latin name of amber, this acid has received the apellation of succinic acid.

It is obtained by the following process:—A retort is filled half full with powdered amber, and the powder covered with a quantity of dry sand; the retort is placed in a furnace, a receiver luted on, and fire applied. There passes over first an insipid phlegm, then a weak acid, which, according to Scheele, is the acetic. The succinic acid then attaches itself to the neck of the retort in the form of crystals; and if the distillation be continued, there comes over at last a thick brown oil, which has an acid taste.

The succinic acid is at first mixed with a quantity of oil. It may be made tolerably pure by dissolving it in hot water, and putting upon the filter a little cotton, previously moistened with oil of amber. The acid is then to be crystallized by a gentle evaporation; and this process is to be repeated till the acid be sufficiently pure. Guyton de Morveau has shown that it may be made quite pure by distilling from it a sufficient quantity of nitric acid, taking care not to employ a heat strong enough to sublime the succinic acid.

As succinic acid is scarcely used for any other purpose than in preparing the succinate of ammonia to be used as a chemical agent in separating iron from

acid solutions, a far greater quantity than is required might be collected by saving the vapours that arise in melting amber for making amber varnish.

Succinic acid crystals do not contain any water of crystallization. According to Berzelius, their composition is $H^4 C^4 O^3$ equal to 627,850; and Dr. Thomson makes it $H^2 C^4 O^3$ or 6,250, which is the same thing in other words. Hence, according to the Glasgow professor, its composition is, so far as remote principles are concerned, the same as that of dry acetic acid, although so different in respect to their union with water, as it requires 100 grains of this liquid to dissolve a single grain of crystallized succinic acid.

PRUSSIC ACID.

This acid was originally called the *acid of Prussian blue*, then, by contraction, the *Prussian acid*, and, for uniformity of name, the *prussic acid:* the theoretical chemists call it now *cyanic acid*, or *hydro-cyanic acid.*

The original process for obtaining it, as given by Scheele, who first separated it, was as follows:—Mix together ten parts of Prussian blue, in powder, five parts of red oxide of quicksilver, and thirty parts of water, and boil the mixture for some minutes in a glass vessel. The blue colour disappears, and the mixture becomes yellowish green. Pour it upon a filter, and after all the liquid part has passed, pour ten parts of hot water through the filter to wash the residuum completely.

Pour the liquid that passes upon one part and a half of clean iron-filings, quite free from rust. Add, at the same time, one part of concentrated sulphuric acid, and shake the mixture. The iron-filings are dissolved, and the quicksilver, formerly held in solution, is precipitated in the metallic state. The mixture is distilled in a gentle heat, the colouring matter came over by the time that one-fourth of the liquor had passed into the receiver. It is mixed, however, with a small quantity of sulphuric acid; from which it is separated by distilling a second time over a quantity of carbonate of lime.

The sulphuric acid may be also separated by means of barytic water. La Planche recommends one-sixth only to be distilled over, and this to be rectified by means of a gentle fire, over one-two hundredth of carbonate of lime, distilling off afterwards, by means of a gentle fire, three-fourths only of the whole. The acid is obtained of a uniform strength by this process.

Gay Lussac obtained his hydro-cyanic acid by distilling crystallized deuto-cyanuret (cyanide, or prussiate, as it is also called) of quicksilver along with two-thirds its weight of slightly-fuming hydro-chloric acid, or muriatic acid, in a stoppered retort. The neck of the retort must be prolonged for about two feet, by a glass pipe of at least half an inch bore, placed horizontally, and containing, in the end next the retort, small pieces of white marble, the remaining two-thirds being filled with chloride of calcium, or muriate of lime. To the

end of this pipe a small receiver must be luted, and be kept cool by a freezing mixture. Hydro-cyanic acid, along with muriatic acid and watery vapour, will be disengaged on gently heating the retort, the last two of which will be condensed by the materials in the pipe, while the acid, by successively heating the different parts of the pipe, may be driven onwards to the receiver.

On repeating this process, Vauquelin found the product of hydro-cyanic acid extremely small. He succeeded better by passing a current of sulphuretted hydrogen gas, produced by acting on sulphuret of iron with sulphuric acid, very slowly through a glass pipe slightly heated, and filled with prussiate of quicksilver, its extremity ending in a receiver, which was kept cool by a mixture of snow and salt. The process was carried on till the extremely fœtid smell of sulphuretted hydrogen was discovered in the receiver. The hydro-cyanic acid he obtained amounted, in weight, to one-fifth that of the prussiate of quicksilver. To avoid any inconvenience from the process being carried too far, some white-lead was placed at the end of the tube next the receiver, in order to absorb the sulphuretted hydrogen that might pass undecomposed.

The action of this acid upon the nervous system of animals is so strong, that a single drop applied to the tongue or eye of a large dog, instantly deprives it of life; but, as modern physicians, on the present fashion of employing the most powerful drugs, have dared to use it in consumptive complaints, great caution is necessary to be taken in its preparation, to secure uniformity of strength.

Some obtain their prussic acid, for medical purposes, by dissolving prussiate of quicksilver in eight times its weight of water, and pass a current of sulphuretted hydrogen gas through the solution, till the liquid contains a slight excess of it, which may be separated by a little white lead, after which the fluid may be filtered for use.

The process adopted at Apothecaries' Hall, London, is the following:—One pound of prussiate of quicksilver is put into a stoppered retort with six pints of water and a pound of muriatic acid, specific gravity 1·16; a capacious receiver is luted to the retort, and six pints are distilled over. The specific gravity of the product is 0·995: it must be preserved in bottles excluded from the light, and being subject to decomposition, should not be prepared in large quantities at a time.

M. Majendie says, that the medical properties of prussic acid, prepared according to Scheele's method, are not sufficiently determinate, on account of the arbitrary nature of the process. It is better to use M. Gay Lussac's acid, taking care that it be properly diluted, by adding six times its measure, or eight times and a half its weight, of distilled water.

Prussic acid, free from water, according to Berzelius, is composed of $C^2 H^2$

NO equal to 235,360; which the chemists of South Europe express by $\dot{C}^2$ $\dot{N}_2$ and Dr. Thomson makes its atomic weight 3,375.

LIQUID HYDRO-SULPHURIC ACID.

This was at first called *water impregnated with hepatic air or gas;* then *water impregnated with sulphuretted hydrogen gas:* the German chemists call it *hydro-thionic acid.*

As it is only used by analytical chemists, to discover the presence of certain metals in a compound mass, it is only prepared in small quantities, and with great care to avoid impurities. Common antimony ground, is put into a retort, and four times its weight of strong muriatic acid is poured upon it; a file of four or five bottles are connected with the retort by pipes, that next the retort has a small quantity of water put into it to absorb the muriatic acid that may come over; the two or three next are half filled with water to absorb the sulphuretted hydrogen gas that is disengaged, and the last with potasse water to absorb any portion of sulphuretted hydrogen gas that may escape the action of the water, and prevent its disagreeable smell of rotten egg from filling the laboratory.

The sulphuretted hydrogen gas which forms liquid hydro-sulphuric acid, is estimated, by Berzelius, as S $\dot{H}_2$, equal to 213,600; and, by Dr. Thomson, as S H, equal to 2,125, which is the same in effect.

Besides these simple acids, there are other acid compounds, that act in many cases as simple acids, although they contain small portions of alkaline matters.

Aqua Regis.

This having been the first solvent that was discovered for gold, the king of metals, was called by this name, signifying the king's water.

The original and proper aqua regis is made by adding four ounces of common salt to an avoirdupois pound of aqua fortis. Homberg says, aqua regis is of proper strength to dissolve gold, when a bottle, holding sixteen ounces of water, holds seventeen ounces of the acid; that is to say, when it is of the specific gravity 1·062.

The theoretical chemists are not agreed respecting the changes that take place in making this preparation.

Aqua Regis made with Sal Ammoniac.

This is made with sal ammoniac instead of common salt, and, like the common aqua regis, dissolves gold; but is more expensive.

In consequence of the presence of ammonia, it forms fulminating gold by adding carbonate of potasse.

Keir's Aqua Regis.

When to a mixture of oil of vitriol with saltpetre a saturated solution of common salt in water is added, a powerful aqua regis is produced, capable of dissolving gold and platinum; and this aqua regis, though composed of liquors perfectly colourless, and free from all metallic matter, acquires at once a bright and deep yellow colour.

The addition of dry common salt to a concentrated mixture of sulphuric and nitric acids, produces an effervescence, but not the yellow colour; for the production of which, a certain proportion of water is thought by Keir to be necessary.

Keir's Aqua Reginæ.

This name is given to this acid liquor on account of its dissolving silver, and having little or no action on other metals, unless water is added; hence it may be metaphorically said that it is the only bath in which the queen of metals can wash herself without intrusion.

It is made by pouring eight or ten pounds of oil of vitriol upon a pound of refined saltpetre.

It is used at Birmingham to recover the silver from the waste scrap of the platers.

Essential Salt of Wood-Sorrel.

Wood-sorrel grows abundantly in Switzerland, and is collected and crushed in wooden mortars, with a hole in the side, by means of large wooden hammers, which are lifted up by the sweepers of the arm of water-mills. The juice thus obtained is cleared by settling for a few days, then strained, evaporated to a pellicle, and set by to crystallize.

The plant yields about half its weight of juice, and from 140 to 200 pounds of the plant are required to furnish a pound of the salt; which is carried from its native mountains to all parts of Europe.

A similar essential salt has also been procured from the common sorrel, but not so easily: both constitute the basis of what is sold by the name of essential salt of lemons; being, for this purpose, mixed with an equal weight, or even more, of cream of tartar.

The genuine salt forms, with sugar and water, an agreeable cooling beverage, much used on the continent, not being so griping as cream of tartar: it is also used, like pure oxalic acid, to take out iron-moulds or ink-spots, and as a test for lime.

This salt is the bi-oxalate of potasse of the theoretical chemists, and may also be formed by dropping carbonate of potasse water into liquid oxalic acid, when it falls in the form of small crystals, but if too much carbonate of potasse is added, the crystals do not separate. Berzelius says, the bi-oxalas kalicus $K{\cdot\cdot}O^{4}$ is combined with two atoms of water, and its atomic weight 3,211,740. Dr. Thomson says it is composed of $K\cdot O^{3}+2\,H$, and makes its weight only 17,250; which is widely different.

White Argol.

This is also called white crude tartar; it is obtained from white wines by keeping, as it settles and forms a crust on the sides of the cask. The wines of the countries in which the grape does not thoroughly ripen, are those which furnish the greatest quantity.

It is used for the manufacturing of cream of tartar; for determining and promoting the fermentation of saccharine liquids, being a neater article than yeast for that purpose; for making a carbonate of potasse; for dyeing; and in medicine; being less apt to gripe than cream of tartar, which is prepared in copper vessels.

White argol is a bi-tartarate of potasse mixed with some tartarate of lime, and a little of the extractive and other carbonaceous matters of the wine.

Red Argol.

This is deposited from the red wines, and contains more of the extractive and other carbonaceous matters of the wine than white argol.

It is used for making a carbonate of potasse for the dyers; for making a fine black for copper-plate printing; for dyeing; and by metallurgic chemists for making their black flux.

Cream of Tartar.

This is also called *crystals of tartar;* and by theoretical chemists, *acid tartarate, acidulous tartarate, bi-tartarate,* or *super-tartarate of potasse;* and in the north of Europe, *bi-tartras kalicus.*

It is manufactured by dissolving white argol in water, adding about one-twentieth of its weight of white clay to absorb the oily and other particles in the argol which colour it, then filtering the liquid, evaporating to a skin, and setting it by to crystallize: if the crystals are not sufficiently white, the process must be repeated.

Cream of tartar has been much used to form an acidulous drink for summer use; but as the cream is prepared in copper vessels, and contains a minute portion of copper, it is apt to gripe. In chemistry it is used as an acid to form emetic tartar, and some other potasse-tartarates.

The composition of cream of tartar, according to Berzelius, is $K \cdot\cdot T^{+4+2} (H^2 O,)$ and its atomic weight 4,742,660; but according to Dr. Thomson, $K \cdot T^{-2} + 2 H$, or 24,750.

Besides these acids which are in use, the analytical and theoretical chemists mention several others; but as they have not yet been discovered to possess any useful properties, a bare enumeration of their names would be misplaced in a treatise on Operative Chemistry.

ALKALIES.

ALKALIES in their original signification meant only the caustic salts extracted from the ashes of plants by washing the ashes with water, and boiling down the liquor to dryness; but at present the chemists denote, by this term, whatever forms a crystallizable compound with the four most usual acids, namely, the sulphuric, nitric, muriatic, or acetic: so that the term, alkaline, has become a mere correlative to acid.

The usual alkalies namely, potasse, soda, ammonia, and lime, have a very caustic taste; are soluble in water, and the solution changes the blue colour of syrup or violets to green; they corrode and dissolve animal flesh, and unite with olive oil; the three first forming with it a compound dissolvable in water.

As the strength of acids is compared by ascertaining the quantity of carbonate of soda which they saturate; so that of alkalies may be compared by ascertaining the relative quantity of concentrated sulphuric acid, or oil of vitriol, that they are able to saturate.

Dr. Ure, who is fond of instrumental chemistry, improved an alkalimeter of M. Descroizilles, for the purpose of ascertaining the strength of alkalies, not in general, but of each kind in particular: but the general use of this instrumental chemistry is to be discouraged, although particular individuals may occasionally apply it to their peculiar uses.

POTASSE, OR KALI.

The original name of this family of alkaline salts was *vegetable alkali*, contracted by Dr. G. Pearson into *veg-alkali*. When about forty years ago a rage for new naming every article used in chemistry was begun, the French nomenclators named it *potasse*, which some have anglicised into *potass*, others into *potassa*, or even *potash*, disregarding the equivocations thus produced. Dr. Black called it *lixiva;* Kirwan, *tartarine;* Bergmann, *potassinum;* Hopson, *spodium;* others have revived the ancient term, *kali*, which is retained by Berzelius, and of course used by the Swedish, Danish, Saxon, and Prussian medical faculty, who have adopted his nomenclature, with occasional slight alterations amongst this variety, potash, potass, potassa, or potasse, and kali, still keep their ground.

Pure potasse or kali is obtainable by burning potassium in oxygen gas, but is not used.

Sir H. Davy found that potassium, heated in a small quantity of atmospheric air, formed a grayish mass. This Berzelius considers as the protoxide of potassium, and calls it *sub-oxidum kalicum*, K· equal to 1,079,830: dry potasse, called by him *oxidum kalicum*, or simply *kali*, is K·· equal to 1,179,830; but Dr. Thomson considers potasse as the protoxide, and of course the atomic weight of potassium to be only half that assigned by Berzelius, so that potasse is K·, equal to 6,000.

Pearl-Ash.

This is obtained from the ashes of wood by washing out the salt with water, and evaporating the ley to dryness.

Most trees are known to be fit for this purpose, as the ashes of them all, burnt promiscuously in house fires, make a very

strong ley fit for soap. The hickory, a most common tree in American woods, produces the purest and whitest ashes, of the sharpest taste, and strongest ley, of any wood. Stick-weed is said to do the same, which is a common American weed. For this reason the ashes of both these plants were used by the Indians there instead of salt, before they learnt the use of common salt from the Europeans. The ashes of damaged tobacco, or its stalks, stems, and suckers, of which great quantities are thrown away, and rot and perish, are very fit for pearl-ash, as they contain a great deal of salt, and are well known to make a strong ley. In England wormwood was frequently used for this purpose.

On the other hand, pines, firs, sassafras, liquid amber, or sweet gum, and all odoriferous woods, and those that abound with a resin or gum, are unfit for making pearl-ash, as their ashes are well known to make a very weak ley.

Besides these, that contain little or no salt, there are some other vegetables that afford a large quantity of it, but make a bad kind of pearl-ash, at least for many purposes, on account of a neutral salt with which they abound. This seems to have been the case of the potash made in Africa; in a manufacture of that commodity set up there by the African company, which Mr. Houston, who was chiefly concerned about it, tells us, in his Travels, proved so bad, on account of a neutral salt it contained, that the manufacture was left off on that account.

The plants used for making pearl-ash should likewise be burnt to ashes by a slow fire, or in a close place; if the plants are burned solely for this purpose. For the difference between burning wood in a close place and the open air is so great, that the quantity of ashes obtained from one is more than double the other.

Lundmark burnt a quantity of birch in a close stove, from which he obtained five pounds of ashes; whereas, the same quantity of the same wood burnt in the open air, yielded only two pounds.

It is for this reason that most people who make potash or pearl-ash, burn their wood in kilns, or pits dug in the ground, though the Swedes burn it in the open air.

Dr. John, of Berlin, has recently found, by experiment, that rotten and decayed wood yields more alkali than sound wood. So Cleaveland, in his mineralogy, says that two bushels of the ashes made by burning the dry wood in hollow trees, contained as much alkali as eighteen bushels of ashes made from sound oak.

One thousand pounds of the following vegetables yielded the under-stated quantity of ashes, and these, by washing, produced salt, mostly carbonate of potasse, as follows:—

	Ashes.	Salt.
Fumitory	219 pounds.	79 pounds.
Wormwood	97	73
Stinging nettle	107	25
Vetches, or tares	—	27
Bean stalks	—	20
Cow thistle	105	20
Stalks of maize	88	18
Great river rush	39	7
Fern	40	6
Vine cuttings	34	5
Common thistle	40	5
Feathered rush	43	5
Elm	24	4
Sallow	28	3
Oak	13	1½
Beech	6	1½
Hornbeam	11	1¼
Poplar	12	¼
Clover	—	¼
Fir	3	—

It having been stated that potato tops might be used with great advantage for obtaining pearl-ash, M. Mollerat made the following experiments on a hectare, or two acres and nearly two roods of ground, planted with a very productive potato, called in France, the yellow patraque.

Period of cutting.	Cuttings produced pearl-ash, in pounds.	Crop of potatos in tuns.
Immediately before flowering	424	2
Immediately after flowering	380	16
A month later	150	30
A month later than the last	130	41
Another month later	the same.	the same.

According to Vauquelin, two ounces of American potash contained 857 grains of potasse combined with 119 of carbonic acid and water, 154 of sulphate of potasse, 20 of common salt, and 2 of indissoluble matters.

The species sold commonly as pearl-ash, contained 754 grains of potasse combined with 308 of carbonic acid and water, 80 of sulphate of potasse, 4 of common salt, and 6 of indissoluble matters.

Potash.

The art of converting wood ashes into potash is practised in Russia, Sweden, and other northern countries, as it was disclosed by Dr. Lundmark, which has been imitated in other places.

They have many woods of beach in Smoland, and other parts of Sweden, in want of which they take alder; of these they use only the old and decaying trees for this purpose, which they cut to pieces, and pile in a heap, to burn them to ashes, on the ground, by a slow fire. They carefully separate these ashes from dirt or coals in them, which they call raking them, after which they carry them to a hut built in the woods for this purpose, till they have a sufficient quantity of the ashes. They then choose a convenient place, and make a paste of these ashes with water, by a little at a time, in the same manner, and with the same instruments, as mortar is commonly made of clay or lime. When this is done, they lay a row of green pine or fir logs on the

ground, which they plaster over with this paste of ashes: over this they lay another layer of the same straight logs of wood, transversely or across the others, which they plaster over with the ashes in the same manner; thus they continue to erect a pile of these logs of wood, by layer over layer, and plastering each with their paste of ashes, till they are all expended, when their pile is often as high as a house. This pile they set on fire with dry wood, and burn it as vehemently as they can; increasing the fire from time to time, till the ashes begin to be red hot, and run in the fire. Then they quickly overset their pile with poles, and while the ashes are still hot and melting, they beat and clap them with large round flexible sticks, made on purpose, so as to incrust the logs of wood with the ashes: by which the ashes concrete into a solid mass, as hard as stone, when the operation has been rightly performed. This operation they call, walla, or the dressing. Lastly, they scrape off the salt, thus prepared, with iron instruments, and sell it for potash. It is of a bluish dark colour, not unlike the scoriæ of iron, with a pure greenish-white salt appearing here and there in it.

All the potash we have from Russia, Sweden, and Dantzic, is made in this manner. It is, however, generally observed, that the Russian is the best of these, on account of the greater quantity of salt in it. Now if, in the preceding process, we make a paste of the ashes with ley instead of water, it is plain the potash will be impregnated with more salt, and make all the difference found so between these sorts of potash. This, then, is likely to be the practice in Russia, where their wood may also be better for this purpose, and afford more salt. This is well known to be the case of different kinds of wood, thus, Lundmark tells us, he obtained two pounds, 27-64ths, of salt out of eight cubic ells of poplar, which was very sharp and caustic, but the same quantity of birch afforded only one pound of salt, and that not so strong, and fir hardly yielded any at all.

Potash differs considerably from pearl-ash, for the best Russian potash, as it is brought to us, is in large lumps, as hard as a stone, and black as a coal, incrusted over with a white salt, that appears in separate spots here and there in it. 2. It has a strong, fœtid, sulphurous smell and taste, as well as a bitter and lixivial taste, which is rather more pungent than other common lixivial salts. 3. A lixivium of it is of a dark green colour, with a very fœtid sulphurous smell and bitter sulphurous taste, somewhat like gunpowder, as well as sharp and pungent like a simple lixivium. 4. Though it is as hard as a stone, when kept in a close place, or in large quantities together in a hogshead, yet, when laid in the open air, it turns soft, and some pieces of it run into a liquid. 5. It readily dissolves in warm water, but leaves a large sediment, of a blackish gray colour, like ashes, which is in a fine soft powder, without any dirt or coals in it, that

are to be observed in most other kinds of potash, or kelp. 6. As it is dissolving in water, there is scummed off from some lumps of it a dark purple bituminous substance, like petroleum or tar, which readily dissolves in the lixivium. 7. This, or any other true potash, or a lixivium made of them, will presently tinge silver of a dark purple colour, difficult to rub off: while a pure alkaline salt has no such effect. Geoffrey found that most of these properties may be given to pearl-ash by melting it with charcoal.

Pieces of this potash, while being boiled in water, made a constant explosion like gunpowder, which was so strong as not only to throw the water to some height, but lift up and almost overset a stone cup in which it was boiled. These explosions were owing not so much to the included air, which some perhaps may imagine, as to the sulphurous parts of the composition expanding and flying off; for this boiled lixivium had neither the green colour, nor fœtid sulphurous smell and taste, at least in any degree like what it has when made of the same potash by a simple infusion in warm water.

According to M. Vauquelin, two ounces of various kinds of potash contained as follows:

Russian potash contained 772 grains of potasse combined with 254 of carbonic acid and water, 65 of sulphate of potasse, 5 of common salt, and 56 of indissolvable matter.

Dantzic potash contained 603 grains of potasse combined with 304 of carbonic acid and water, 152 of sulphate of potasse, 14 of common salt, and 79 of indissolvable matter.

Treves potash contained 720 grains of potasse combined with 199 of carbonic acid and water, 165 of sulphate of potasse, 44 of common salt, and 24 of indissolvable matter.

Vosges potash contained 444 grains of potasse in combination with only 16 of carbonic acid and water, 148 of sulphate of potasse, 510 of common salt, and 34 of indissolvable matter.

English Potash.

There is another way of making potash, practised chiefly in England, with ashes of fern, or wood of any kind: they make a ley, which they reduce to what they call potash, by burning it with straw. To do this, they place a tub full of this ley near a clean hearth of a chimney, in which they dip a handful of loose straw, so as to take up a quantity of ley with it. The straw thus impregnated with ley they carry as quickly as they can, to hold it over a blazing fire on their hearth, which consumes their straw to ashes, and at the same time evaporates the water from the salts of the ley. Over the blaze of the first parcel of straw they burn another dipped in ley in the same manner. This they continue to do till their ley is all expended. By this means the coals and ashes of the straw, and salts of the ley, are left on the hearth, and concrete together into a hard solid cake of a grayish black colour, which they scrape off and sell for potash.

This potash is unfit for some purposes, and not above half the value of the foreign.

[It is a little remarkable, that no mention is made by the author, of American pot and pearl-ashes; they are well known in the English market, and extensively used in the arts of Great Britain, possessing a decided superiority in point of purity, over those of any other country. The processes of manufacturing the pot and pearl-ashes in the United States and in the Canadas, is very simple, but by no means so economical as they might be. In general, the clearing the land of wood, is the primary, and the manufacture of these articles only a secondary, object. The wood is usually cut into lengths of eight or nine feet and thrown into piles of one, two, or more cords, and, when partly seasoned, set on fire. The woods which are cut in summer are said to be the most productive in alkali. The ashes resulting from the combustion are, when cold, gathered up and put into large tubs, the bottoms of which are covered to the depth of 6 or 8 inches with brush-wood, and over that with a layer of three or four inches of straw. Water is then poured upon the top, and suffered to filter through till all the soluble matter of the ashes is extracted. The ley runs off through an aperture near the bottom of the tub designed for that purpose. It is then boiled in large cast-iron kettles till the water is all evaporated, and the matters, which were held in solution, obtained in a solid form: this product is familiarly known to the workmen by the term of *brown salts*, or *salts*, simply; it is of a very dark,—almost black, colour, and a very strong alkaline and acid taste, and consists of a very large proportion of potash, mixed with more or less carbonaceous matters, vegetable salts of potash, and small portions of silex and other earths. To convert these brown salts into potash they are again thrown into a cast-iron kettle of considerable thickness, fused and subjected for an hour or two to a full red heat after the mass is perfectly liquid. By this means the carbonaceous matters are for the most part decomposed and burned out. The remaining product is, when cold, broken up and packed in tight casks, and constitutes the American potash of commerce. It contains from five to twenty per cent. of pure potash, combined or mixed with variable proportions of carbonic acid, and compound carbonaceous matters, silex and other earths, the proportions and quantities of the latter depending very much upon the care which may have been used in collecting the wood ashes after the combustion. The potash of commerce is usually divided into four sorts according to the degrees of purity of each.

If the salts obtained by the evaporation of the ley in the first instance are redissolved in a small quantity of water, there will be a considerable deposite of less soluble earthy substances, and

the clear liquor when evaporated, will afford a much purer product than that obtained in the common way, and the potash resulting from it will be proportionally purer. This plan is indeed adopted by many potash makers. Unskilful manufacturers of potash are sometimes much troubled with the presence of nitrate of potash in melting down the brown salts; this difficulty is remedied by mixing with the brown salts, previous to melting, a small quantity of powdered charcoal. It is probable that nitric acid, (and, of consequence, nitrate of potash,) is always a product of the combustion of wood in the open air; but the quantity varies with the circumstances of the combustion, and in ordinary cases, the carbonaceous matter in the brown salts are sufficient to decompose it without the addition of charcoal.

In the manufacture of pearl-ash the process is the same up to the production of the brown salts. They are then thrown into a reverberatory, and calcined till the whiteness of the product indicates the entire dissipation of all carbonaceous and volatile matters. The salts are, of course, stirred or raked frequently, during this process, which is called *pearling*. The product is the pearl-ash of commerce, a sub-carbonate of potash, uncontaminated by vegetable matter, but containing more or less of earthy impurities, derived principally from the bed upon which the wood was burned. Particular care is taken that the temperature do not rise so high in the pearling as to cause the salt to melt, as upon this circumstance the superior purity of the pearl-ash in regard to carbonaceous substances, depends.

The immense supplies of pot and pearl-ashes for the arts and for exportation, are, in this country, derived exclusively from the combustion of forest timber. Owing to the great abundance of wood, no attempt has been yet made on an extensive scale to procure them from the smaller tribes of the vegetable kingdom.

The source of potash, as obtained in the combustion of wood, is an unexplained problem in chemistry.]

Purified Pearl-Ash.

This has been ordered under different names, according to the fashion of the times when the College of Physicians published their Pharmacopœias. In the old editions it bore the name of the fixed salt of the plant from which it was extracted, generally *wormwood*. In 1788, it was *prepared kali*; in 1809, *sub-carbonate of potasse*. It is also sold under the name of *salt of tartar*.

It is prepared by pouring half its weight of water upon good pearl-ash, filtering the solution, and evaporating it in copper pans until it becomes perfectly dry, which is particularly requisite, as otherwise it will not acquire the usual granular appearance, by stirring as it cools.

...eatest part of the sulphate of potasse and ... which is left upon the filter, but some sulphate ... of potasse pure enough for medical and ...

Carbonate of Potasse Water.

... being used in analytical and docimastic experi... ...s attention as to its purity and strength.

... ...y prepared by throwing a mixture of charcoal pow... ...ve times its weight of purified saltpetre, by degrees ... ...ot silver crucible, taking it from the fire as soon as ... ...ion is complete, washing out the salt with distilled ... ...d filtering it through well-washed sand or powdered ... The specific gravity is then to be ascertained, and the ... ...n either reduced by adding distilled water, or, which is ... commonly requisite, concentrated by evaporation until the ... ...ired specific gravity is obtained.

Dr. Henry advises it to be kept of the specific gravity 1·248, as it will then ... ...e equal measure of sulphuric acid at 1·145, or of nitric acid at 1·14, ...muriatic acid at 1·1 to be of equal strength with ammonia water at ... ...; and that a mixture of equal parts of water at 1·1 and pure soda water at 1·0... ... of soda water at 1·11 will require about ... of ammonia water at 0·96. ... ...*Solution of potash*, used in medicine, is an impure preparation ... ...kali, made from purified pearl-ash: it is also called *aqua kali*, and *ley* ... ...*potash*.

The ... of potasse has been given by the chemists to the com... ... with a single charge of carbonic acid, ... with a double charge of carbonic acid. ... of potasse is thus render... ... in the chemical sense of the term, has yet been not improperly, by packing together the sub-carbonate of the ... and facility of the chemical schools, an unequivocal ... ...ation of the carbonates may be obtained.

Aerated Kali.

... ...s name of aerated kali, is the ... of potasse of the ... ...; and the ... of the chemical schools ... ...; under the name ... ...; which ... kali impregnated with ... ...; being, strictly speaking, ... with ...

It may be made by passing carbonic acid gas into purified pearl-ash water; by Glauber's or Woulfe's apparatus: care being taken that the pearl-ash water is not too strong, as in that case the aerated kali crystallizing as it forms, would stop up the pipes. The silica contained in the pearl-ash is separated by not being soluble in water in the saturated salt, and the aerated kali may be crystallized by evaporating the liquor to a pellicle.

M. Curaudau's process of making aerated kali is, to dissolve pearl-ash in water, and incorporate with it dried tan, bran, or

saw-dust, till all the liquid is absorbed. A crucible is filled with this composition, covered with a lid, and the joints luted.

This crucible must be submitted to the heat of a furnace about half an hour, or till it is thoroughly red-hot. When the crucible is cold, put upon a filter all the matter contained in it, and pour on it a sufficient quantity of water to dissolve it quickly. Then evaporate the liquor to a very small quantity; and, after it has been left to cool about twenty-four hours, it will furnish very beautiful crystals of bi-carbonate of potash.

It is more advantageous to perform the operation on a large than on a small scale; as the rapidity with which small quantities cool, frequently prevents the formation of regular crystals.

After all the carbonate, which the ley held in solution, has been obtained, by several evaporations and crystallizations, the mother water may be submitted to calcination with tan, and thus a fresh quantity of crystals of bi-carbonate of potash will be obtained, until the liquor at length becomes more surcharged with other salts than with potash.

Mr. Lowitz has proposed another process.

A quantity of purified pearl-ash is to be dissolved in an equal, or, which will be still better, in double its weight of water; and the solution being filtered, there must be added to it, by small quantities at a time, (the liquor being kept stirred during the whole of the operation,) distilled vinegar, which should be poured down in a thin stream from as great a height as the hand can be held, till neither stirring the liquid with vehemence, nor frequently intermitting the effusion of vinegar, can any longer prevent the effervescence which does at last take place. The fluid must now be filtered, and evaporated over a very slow fire, till a film of salt appears upon it. After it has completely cooled, the impure carbonate of potasse, which has deposited itself in small irregular crystals, is to be separated by filtering the mixture through a linen bag; and the fluid must be evaporated and filtered once or twice more, and the whole of the salt obtained purified by repeated solution and crystallization, till it forms perfectly white and regular crystals.

By this process the carbonate of potasse will not only be freed from the acetate that adhered to it, but likewise from all admixture of carbonate of potasse which will remain behind in the original lixivium.

For the same purpose of obtaining aerated kali, sulphuric acid may be used; but it must previously be diluted with a large proportion of water. In this process, after evaporation, the sulphate of potasse first crystallizes, and then the bi-carbonate. A residuum of carbonate of potasse also remains in the original lixivium.

A bi-carbonate of potasse may be obtained by the means of sulphur, in the following manner:—Any quantity of purified pearl-ash must be dissolved in two or three times its weight of water. The solution must be gently boiled, and flowers of sulphur gradually added, till no more appears to dissolve. The fluid is then to be evaporated very slowly to the point of crystallization, and the crystals obtained purified by repeated solution, filtration, and crystallization from their admixture with sulphuretted potasse and carbonate of potasse.

This method requires far less evaporation of water, and affords crystals of the purest aerated kali. The principle upon which it depends is this: the sulphur only uniting with the potasse of the pearl-ash, causes the carbonic acid to concentrate itself in the remaining potasse; so that if the proper proportion of water has been added in the beginning, the aerated kali frequently deposites itself by crystallization, immediately after the liquor has cooled, without requiring any farther evaporation.

As that part of the carbonic acid, whereby the neutralization of the kali is completed, is so very slightly combined with it, that the slightest increase of temperature causes a part of it to separate in the form of carbonic acid gas, it is therefore very necessary, in purifying this salt, to pay particular attention, in order to prevent the solution from boiling; for the greater heat we employ, the more carbonic acid will be wasted.

In pharmaceutical laboratories, bi-carbonate of potasse may be obtained from the residuum which remains after the distillation of tartar, by lixiviating it without previous calcination, and evaporating the fluid to the point of crystallization, after which, by repeated solution and evaporation, the crystals may be freed from all admixture of common carbonate of potasse.

[The aerated or carbonate of potash, is extensively used in the United States in the domestic manufacture of bread, in medicine and for other purposes. It is very economically prepared by the distillers and brewers from common pearl-ash by suspending it in lumps in a wooden box pierced with holes in the upper part of their fermenting vats, which are always occupied with an atmosphere of carbonic acid. In a few days' time, longer or shorter, according to the quantity operated on, the alkali becomes completely saturated with the acid. The salt prepared in this way, will not have the crystalline form, but is equally useful for all the purposes of the arts. Its purity will of course depend upon the purity of the pearl-ash employed.]

Hydrate of Potasse.

The common hydrate of potasse, sold by the apothecaries as *potassa fusa*, is prepared by merely boiling down their liquor potassæ to dryness, and then pouring it out upon a stone slab,

and cutting it into pieces, from which the air is to be kept carefully excluded.

Berthollet recommends to boil down potasse-water till it acquires a thickish consistence, to add about an equal weight of spirit of wine, and let the mixture stand some time in a close vessel. Some solid matter, partly crystallized, will collect at the bottom; above this will be a small quantity of a dark-coloured liquid; and, on the top, another lighter. The latter liquid, separated by decantation, is to be evaporated quickly in a silver basin in a sand-heat. Glass, or almost any other metal, would be corroded by the potasse. Before the evaporation has been carried far, the solution is to be removed from the fire, and suffered to stand at rest, when it will again separate into two fluids. The lighter being poured off, is again to be evaporated with a quick heat: and, on standing a day or two in a close vessel, it will deposite transparent crystals of pure potasse. If the liquor be evaporated to a pellicle, the potasse will concrete without regular crystallization. In both cases a high-coloured liquor is separated, which is to be poured off, and the potasse must be kept carefully secluded from air.

Hydrate of potasse is composed of a proportion of each, potasse and water, according to Mr. Phillips and others, but Berzelius makes it K: + 2(H H·) equal to 1,404,700; indeed it so strongly retains part of the water, that chemists do not agree how much water 100 parts of it contain. Phillips says 15 parts ·8, Thenard 20, Berzelius 16, Thomson 15·4.

Nitre fixed by Antimony.

For obtaining an impure but very dry and caustic kind of potasse, chemists act upon saltpetre, by means of regulus of antimony.

Four ounces of the regulus is mixed with eight of refined saltpetre, and kept for an hour in a strong fire in a large crucible; four ounces more saltpetre are then added, in another hour four ounces more, and in another hour four ounces more, in all twenty ounces; the heat must, in the end, be so strong, that the mass may swell up and effervesce, and this heat continued until the mass is in quiet fusion, and as fluid as water, when it is to be poured out into a basin, and bruised into pieces.

The extreme causticity of this greenish semi-transparent mass, seems to arise from its not containing water. When spirit of wine is poured upon it, it grows hot, and slakes as violently as quick-lime does with water, the spirit becomes instantly milk white, and, after a short digestion, deep blood red.

Potasse Water.

This water is used in docimastic chemistry, and, must, therefore, be kept as pure as possible. It is usually prepared by mixing refined saltpetre with twice its weight of cream of tartar,

both in fine powder, throwing them into a cast-iron crucible, nearly red-hot, by which a very nearly pure sub-carbonate of potasse will be obtained. This, or any other equally pure sub-carbonate of potasse, is to be mixed with an equal weight of good quick-lime, and five times its weight of distilled water; the whole is boiled together in a basin, until, on filtering a spoonful of the liquid, and pouring lime-water into it, no sediment is formed: the whole is then poured on a strong linen cloth, placed on a colander in the mouth of a funnel: the first liquor that passes is thrown again on the filter. The specific gravity of the filtered liquor being examined, it is boiled down to the required strength. During both the boilings and the filtering, the vessel should be kept covered to prevent the access of the atmosphere, from which the liquid would absorb carbonic acid gas.

Dr. Henry advises it to be kept of the specific gravity of 1·100; so that two measures of it may saturate one measure of sulphuric acid at 1·135, of nitric acid at 1·143, or of muriatic acid at 1·074.

An impure potasse-water, sufficient for medicines, is sold as *liquor potassæ*, and is made from a troy pound of purified pearl-ash, half a pound of quick-lime, and a wine gallon of distilled water, mixed together, and the liquid strained through a cotton bag: the medical faculty order that a wine pint should be of such specific gravity as to weigh sixteen troy ounces. This liquor is also called, in common parlance, *soap-ley*.

Potasse-water should be kept in small bottles, quite full and well stopt; in a large bottle, the atmospheric air gets in every time it is opened, and the water imbibing carbonic acid gas soon gets spoiled, and a sediment is produced on adding lime-water.

Sal-enixum.

This was at one time a favourite nostrum in Germany, and was sold under a variety of names. Its real chemical appellation was *vitriolated tartar*, from its original mode of preparation by Angelus Sala, by adding fixed salt of tartar to very weak copperas-water, filtering the liquid, and crystallizing it by evaporation and rest. It is the *sulphate of potasse* of the new nomenclature.

It is now procured as a secondary product, from the residuum in making nitric acid; adding pearl-ash, wood, or fern-ash, if necessary, to neutralize the sulphuric acid. It contains no water.

This salt is used by workers in metals as a flux, also to impregnate wood to secure it from the dry-rot; and, being very hard, the medical faculty use the crystals to mix with tough gums, that they may be reduced to powder. In France it is used to change the native nitrate of lime into saltpetre, and in the manufacture of potasse alum.

Saltpetre.

The saltpetre used in England is now obtained from the East Indies, where it is produced by nature.

The saltpetre earth, according to Heyne, attracts a little moisture at night, and appears like a black foot dust at the bottom of old walls, or on the streets of populous or old villages. It

does not differ in appearance from that which yields salt or soda; and, indeed, one village or one street frequently contains all the three salts.

The most profitable way of preparing saltpetre is, to evaporate it in shallow basins of mortar.

The earth is swept up every other day, and contains about one-fifth of crude saltpetre. Thunder and lightning are esteemed favourable for its production. After the saltpetre is extracted, the earth is heaped up till the rains are over, and then spread out; in a year or two it yields saltpetre again.

About two gallons of saltpetre earth is collected at the foot of each yard of wall. The saltpetre gained from black cotton ground contains more common salt than that from garden earth.

The pans of mortar are filled about four inches deep, about half is evaporated in four or six days, and the saltpetre begins to crystallize. The first day's product is the purest; the second day's contains about half common salt; the third day's contains scarcely a quarter of saltpetre. The remaining liquid is thrown upon the elixated earth, has a caustic burning taste, and contains scarcely any thing but nitrate and muriate of lime.

Saltpetre is always refined by boiling, adding soap, milk, eggs, twigs of euphorbia tirucalli, and single, refined saltpetre, still contains about a quarter of common salt.

Bengal saltpetre is browner than that of the coast.

If saltpetre is kept or prepared in any apartment, it is difficult (at least in India) to prevent the destruction of the walls by the continual production of the salt.

Saltpetre grounds are not so common as reported, common salt and soda grounds being mistaken for them.

Calcareous earths, impregnated with saltpetre, are found in caverns in limestone, in various places.

The saltpetre earth of Georgia, United States, contains both the nitrate of potash and that of lime; the latter is changed into saltpetre by adding wood ashes; one bushel of earth yields from three to ten pounds of saltpetre, selling there for sixteen cents (eight pence) by the pound.

Kentucky saltpetre earth is similar to this; it is washed, and the ley passed through wood ashes; a bushel yields from one to two pounds of saltpetre.

Similar earths are found at Molfetta, Naples, Hungary, and various other places in Europe.

Kentucky rock ore is a sand-stone which, when broken to fragments, and thrown into boiling water, soon falls into sand; and the liquor strained from it yields, by crystallization, from ten to twenty pounds of nitre from each bushel of stone. This

nitre contains little or no nitrate of lime, and is considered better for gunpowder than that obtained from Kentucky nitre earth.

Masses of saltpetre of several pounds weight, are sometimes found in the fissures of this sand-stone, accompanied with masses of a black bituminous substance of a few ounces in weight.

Similar sand-stones are found in South Africa, according to Barrow.

The saltpetre formerly used in England was extracted from the mortar of old buildings, as it is still in France and Prussia.

The mark the saltpetre workers have to know good mortar for their purpose is, that it tastes acrid and salt when applied to the tongue; but to this it may be also added, that it ought to be of a grayish colour, and such as, when powdered and sprinkled upon burning charcoal, yields some sparks of fire; and the more sparks it gives, the better it is for the purpose. Another character of the goodness is, that these well-impregnated mortars have a certain unctuosity or fattiness to the touch, which other kinds have not.

The finest of all kinds of mortar for saltpetre work is such as is had from the ruins of old buildings in a low situation, and out of the way of much sun-shine, where there has been no great quantity of fire kept, and especially such as served for the mortar of the walls of stables.

In Prussia, the rubbish of old buildings is built up in thin long walls, sheltered from the weather by straw coverings, and sprinkled with urine of all kinds, for the purpose of generating the salt.

Professor Kidd, of Oxford, has made some curious observations on the production and occasional disappearance of saltpetre on the surface of the lime-stone, of which the Ashmolean laboratory is built, and some other walls in that city. These observations are too long for insertion in this work. He found a clear dry frosty air particularly favourable to the production of saltpetre, and that it disappeared on the approach and during the continuance of a snow storm.

Dr. Ward and some other persons attempted to revive the manufacture of English saltpetre, but were unsuccessful; saltpetre contains no water.

Gunpowder.

The principal consumption of saltpetre is in making gunpowder, the invention of which has totally changed the mode of warfare from that formerly used.

The country people in Russia, Poland, and Tartary, make gunpowder themselves, from private receipts, mixing saltpetre, sulphur, and charcoal dust, in various proportions, and boil them

in water for two or three hours until all the water is evaporated and the composition become very thick; they then take it out of the kettle and dry it in a flat pan placed in the sun, or a warm place, and when nearly dry force it through a sieve, and form it into very small grains. Others grind the composition with water on a slab. The powder thus made is allowed to be equal, if not superior, to that produced by the great manufactories.

The Hon. G. Napier makes the following observations on gunpowder, deduced from a series of experiments when superintending the Royal Laboratory at Woolwich.

The method he has generally adopted for detecting the impurity of nitre, is to drop a strong solution of sugar of lead into a phial of distilled water, saturated with saltpetre; which, if it retained any considerable portion of marine salt or magnesia, assumed a turbid milky appearance. The lunar solution is too powerful a test; but it does not always follow that the purest nitre produces the strongest powder. The best is the Russian; yet the manufacturers in that country are not very solicitous about the magnitude of the crystals, the whiteness of the salt, nor even its freedom from heterogeneous substances; though with us those qualities are accounted essential. In Russia, they seldom refine their nitre more than twice; and it has been found that their saltpetre contains a considerable portion of marine salt and magnesia.

There is reason to believe that powder made with saltpetre oftener than four times refined, is of inferior strength, though probably more durable, than with that which has been only thrice depurated. If the elastic and expansive fluid contained in nitre, partakes at all of a spirituous nature, may not repeated evaporation liberate a portion of it?

It may not be a very improbable deduction to suppose that repeated elixation in part, deprives this salt of that elastic fluid which constitutes the strength of gunpowder. This opinion is strongly corroborated by two well-known facts: first, in purifying a large quantity of nitre, there is a deficiency of weight, after the process, which cannot be accounted for by the weight of the residuum; and, secondly, as great a proportion of saltpetre cannot be extracted from damaged powder as is obtained from serviceable, though originally manufactured with the same quantity of nitre.

Mr. Napier prefers saltpetre, whose crystals are of a moderate size, solid, transparently white, which do not readily break with a crackling noise when gently grasped in the hand, and which, when ignited in a red-hot shovel, do not decrepitate, but melt and consume with an equable and continued inflammation. The first of these symptoms is produced by hasty and imperfect de-

siccation; and the last is a proof that the marine salt has not been entirely separated from the nitre.

If the powder maker refines his nitre himself, he is advised to boil it thrice, carefully skimming off the feculent matter which floats on the surface, filter it through canvas, and leave it to crystallize in leaden or copper vessels, exposed to a free circulation of air in a dry situation, and not in a cold cellar, which is frequently, though erroneously, practised.

The mother-water which oozes from the pans is commonly sprinkled on earth intended for generating saltpetre. Instead of this, were the refiner to add to the mixture a small quantity of wood ashes, and repeat the operation of extracting, he would find it advantageous. He would also save considerably by substituting iron boilers and leaden pans to his copper ones.

On chemical principles, we should prefer charcoal made from wood, containing the greatest quantity of fixed salts, and whose ashes abound with alkaline salts, as such inflames more rapidly, and burns with greater vehemence. Dog-wood (*cornus sanguinea*) and alder (*rhamnus frangula*) are esteemed by powder makers the fittest for their charcoal. Green wood being harder when charred than dry, admits of a more complete comminution, and is consequently better adapted to that intimate combination of the ingredients necessary for the strength and durability of gunpowder.

A manufacturer of gunpowder ought never to use sulphur which he has not purified and sublimed himself. The best method of doing this is by melting it in an iron pot, over a gentle coal-fire which does not blaze, and straining it through a double linen cloth. The operation must be repeated till there appears little or no residuum. When sulphur is bought in a prepared state, it is frequently adulterated with wheat flour, which, in moist or hot climates, readily induces fermentation, and irrecoverably decomposes the powder. Inattention to this circumstance is a principal cause of British gunpowder being less durable now than formerly.

After an accurate examination of powder manufactured according to the most approved practices of Europe and Asia, together with the numerous variations of the chemist, Mr. Napier found it beyond his experience to give a decided preference, as he had seen them all succeed and fail. He therefore recommends that the proprietors of powder mills should manufacture a small quantity of powder from each fresh assortment of materials. In doing this, the following canon, which is borrowed from the French fire-workers, and established by experiments, may be found useful. Begin with 48 ounces of nitre, and nine ounces of charcoal; these will explode without sulphur. In-

crease the quantity of charcoal till the most forcible combination of those two ingredients is discovered, which will commonly happen at between 12 and 16 ounces of charcoal to the 48 ounces of nitre. To this composition let sulphur be added, beginning with half an ounce, till the strongest explosion is found; which will be when the proportion of this ingredient to the above is from 2¾ to 3¼. Finally let the dose of charcoal be diminished, till the composition no longer gains in the eprouvette. This will commonly happen when the proportions of the three materials stand as follow:—nitre, 48 ounces; charcoal, 8½ to 9½; sulphur, 2¾ to 3¼.

The manufacturer, by adopting this method of ascertaining their qualities, however troublesome it at first appears, will in the end be a considerable gainer. There are various opinions respecting the liquid most eligible to moisten the ingredients, during the process of preparing them for the mill. Urine, vinegar, spirit of wine and water, plain water, have severally been recommended for this purpose. Mr. Napier tried them all, without being able to establish any data on which to found a decision. Yet, the volatile nature of spirits, and the heterogeneous matter to be met with in urine and vinegar, seem to point out a preference due to pure water. But, as this is warmly contested, and Mr. Napier's experiments have exhibited no conclusive superiority, he does not seem willing to hazard a determination on the subject. Having, however, procured some powder manufactured at Canton, he analyzed two ounces of it, and after repeating the operation six times, the mean result gave the following proportions:—nitre, 1 Troy ounce, 10 dwts.; charcoal, 6 dwts.; sulphur, 3 dwts. 14 grains. Here is a deficiency in weight of ten grains, probably the consequence of some defect in Mr. Napier's process, which was, first to weigh the powder, next to separate the nitre by solution, evaporation, and filtering. He then weighed the residuum of charcoal and sulphur combined; and lastly he sublimed the sulphur, by a degree of heat not sufficient to inflame the charcoal, which, when weighed, completed the operation, producing the aforesaid result. But as M. Baumé, a French chemist, made a variety of experiments to obtain a total separation of the sulphur from the charcoal, and was never able to effect it, one-fourteenth part remaining united, three grains must be deducted from the charcoal, and added to the sulphur, to give the accurate proportion of the ingredients.

This powder was unusually large grained, not strong, but very durable; it had been made many years when Mr. Napier obtained it; yet there was no visible symptom of decay, the grain being hard, well coloured, and though angular, which form commonly generates dust, it was even sized, and in perfect preservation.

The combining and incorporating the ingredients should be performed, if possible, in clear dry weather;—a lowering sky, and a humid atmosphere, being found inimical to that thorough blending of the materials which ought to precede their being worked in the mill. Stamping mills were formerly used for working gunpowder. Their construction was very simple; it consisted of a large mortar, in which a ponderous wooden pestle, moved by men, by horses, or by water, performed the operation very perfectly, but with obvious danger to the workmen.

In Sweden, and it is believed in Russia, they still continue to stamp the powder, during the first part of the process, and afterwards to roll it under stones. By this means the probability of an explosion is lessened; as the composition is less inflammable in the beginning, than when the materials are more intimately blended.

Since government, alarmed by the frequency of accidents, thought proper to prohibit stamping in the Ordnance-mills, this part of the process has been effected by means of two stone cylinders, moved in a vertical position round a circular trough.

The inferiority of the present practise is visible in its operation on the powder, which has certainly degenerated, both in strength and durability, since the abolition of stamping mills. This may be attributed, first, to neglect in the manufacturer, who is satisfied with working his powder seven or eight hours, instead of twenty-four; and secondly, because the circumferences of two smooth and ponderous stones compress the moist paste into a hard solid cake, over which they make repeated circumvolutions, without contributing much to the incorporation of the ingredients.

Mr. Napier suggests an alteration in the substance and construction of the rollers, to remedy some of the defects in the process of milling. Instead of marble and granite, Mr. Napier proposes that the rollers shall be made of cast iron, as well as the circular trough in which they move; and the periphery of the cylinder be divided into eight equal parts, alternately grooved and plain, with two of the fluted divisions having their grooves transverse, the other two longitudinal. These grooves should be an inch in breadth, and a quarter of an inch in depth, with their angles rounded off. The trough must continue smooth, as in the present practice. The effect proposed from this construction is, that the alternations of the plain and fluted divisions will penetrate the substance of the paste, producing a more intimate connexion and intermixture of the component parts. Or the manufacturer may break the contiguity of the paste by affixing a small but weighty harrow, with copper teeth, to the axis of the roller, and following its direction in the

trough. Iron cylinders are already used in several mills, and the intelligent powder makers allow that accidental explosions are most frequently produced by the collision of chips which break from the edges of stone rollers. The paste, if very moist, may adhere to the grooves; but this will be prevented by the application of oil, in small quantities, to the fluted surfaces. Another alteration is simply working four rollers in the same trough, instead of two.

The process of granulating powder is performed by a horizontal wheel, on which are fixed circular sieves with parchment bottoms, perforated to the largest intended size of the grain. In these sieves the paste is deposited, and with it, in each of them, a small oblate spherical piece of lignum vitæ, which being moved about the sieve by the action of the wheel, breaks the composition and forces it through the parchment bottom, into vessels placed for its reception. But as this operation leaves the powder in grains of various dimensions, it is sorted by being passed through wire screens of progressive sizes.

Gunpowder is commonly dried in a room, three sides of which are furnished with ledged shelves, containing the composition; and the fourth is occupied by a large iron stove which projects into the room, but is heated from without. An amendment has been attempted, by carrying flues round the drying-room fitted with steam: the change has, however, been little, if at all for the better.

The powder returned as unserviceable, which still retained its grain, was usually separated from the dust; and if two drams of it, when tried in the vertical eprouvette, had sufficient strength to project a superincumbent weight of twenty-two pounds to the height of three inches five-tenths, it was again issued for service. But this happening very rarely, a doubt was suggested, that by taking away the dust, the powder was deprived of its principal ingredient. This conjecture was established by repeated experiments in the vertical and mortar eprouvettes; as the dust, though varying in degree, almost always exhibited superior strength to the granulated powder from which it had been separated.

With the assistance of a convex lens, Mr. Napier discovered a new crystallization of the nitre, called by powder-makers the starting of the petre; the minute salts of which, broken by attrition, were converted into that dust which consequently contained the essence of the composition.

When powder is so far damaged as to cake, all attempts to renovate it are nugatory. It should be immediately transferred to the extracting house.

The strength of new powder is not diminished by reducing it to dust, but rather increased. This is a secret well understood

by powder-merchants, who mix dust, in small quantities, with that powder they apprehend will not rise to proof.

It was formerly the practice of government to manufacture their powder as small in the grain as that made at Dantzic or Battel is at present. Whether the large corned powder now used merits a preference is problematical.

In 1782, there were discovered at Purfleet some barrels of very small-grained powder, manufactured by Sir Polycarpus Wharton, surveyor of the ordnance in Charles the Second's reign. It may not be improper to remark, that during this reign, and for some time after, most of the nitre used in England was manufactured at home; and if it be not a mistake, there still exist acts of parliament granting the crown the soil of shambles and slaughter-houses, and the earth under the flooring of stables, bullock-hovels, &c., and also directing the magistrates to have tubs placed in the streets of populous towns for the collection of urine. From these materials there was a sufficiency of nitre extracted to supply the ordinary consumption of government.

Formerly government manufactured three sorts of powder, viz. mortar, cannon, and musket, the first having less saltpetre than the last. The practice should be revived; as sulphur, by its proneness to fermentation, is the ingredient which contributes most to the decomposition of powder. Mr. Napier directed a small quantity to be made from nitre and charcoal, and was surprised to find that fifteen pounds of it projected a thirteen inch shell as far as the best powder composed in the usual manner. Hence, a powder might be made sufficiently strong when used in quantities above ten pounds, with a much less proportion of sulphur than the present practice admits of. In cases where a smaller charge is used, or where a rapid inflammation is required, the usual dose of sulphur is indispensably necessary.

The process of glazing powder is effected by attaching casks, something more than half full, to the axis of a water-wheel; which turning with velocity, the operation is completed in a short time by the friction of the grains against each other. Mr. Napier found from a mean of near six hundred experiments, that glazing of powder reduces its strength about one-fifth, if the powder is good; and nearly a fourth, if of an inferior quality. The proportion of dust separated during the operation is invariably stronger than the glazed powder from which it has been screened.

Government powder, manufactured at Feversham, when received from the mills, is considerably stronger than either Dantzic or Battel shooting powder; and it would continue so were it secluded from the action of the atmosphere. In Dutch men of war, they have an ingenious and safe mechanism for ventilating

their magazines, worthy the imitation of the British navy. In barrelling powder it is of the utmost importance to select dry clear weather; the consequences of inattention to this material point have been oftener felt than suspected by our fleets and armies.

The general preference is due to powder of a moderate size; and somewhat spherical grain. The colour should be a grayish blue, tinged with red, and the texture of the grain firm, but not so hard as to resist a very forcible pressure from the finger against a board. British powder-makers prefer a dark blue colour, and an angular grain, thinking that hue and form susceptible of the readiest inflammation; but numerous experiments convinced Mr. Napier of their mistake.

The strength of powder is frequently impaired by being too precipitately dried. On examining some of the rooms, the crevices of the walls and shelves were filled with flowers of brimstone, sublimed, by the action of the fire, from the surface of the grains, precisely where the greatest proportion of this inflammable principle is required. The acceleration of the drying process has this farther disadvantage, that it leaves the powder moist in the centre of the grain. Such powder, when fresh from the drying-house, will rise to high proof; but being left in the magazine for a month, will lower its strength at least a fourth. Powder should not be proved sooner than two months after being manufactured.

It was formerly the practice to load with large quantities of powder: to demonstrate the absurdity of this practice, the vertical eprouvette was enclosed so as to prevent the escape of uninflamed powder; and after fifty discharges, in each of which two drams were compressed by a weight of twenty-two pounds, three drams and a half of strong and highly inflammable powder were collected. The present charge is a third of the shot's weight for heavy, and a fourth for light artillery: it would still admit of reduction.

Salt of tartar may be introduced as an auxiliary in the composition of gunpowder. It increases the report astonishingly, but is noxious to strength and durability. A powder might be manufactured, a small portion of which would produce a tremendous report, and prevent the unnecessary expenditure of that which is serviceable in the parade of war, where noise only is required. The strength of powder is by no means established by the proof of the vertical eprouvette, unless corroborated by the brass mortar.

It was represented by the Hon. Wellesley Pole, at the House of Commons, in a debate on the Ordnance estimates, in March, 1810, that the excess in the consumption of gunpowder was occasioned by the impossibility of keeping it dry at sea. The

same complaint was again urged by the Hon. Ashley Cooper, in April, 1811, who also stated that the floating magazines were too damp for the stowage of gunpowder. Sir William Congreve, Comptroller of the Royal Laboratory, in a statement of facts, dedicated, by permission, to the Earl of Mulgrave, Master General of the Ordnance, confirms the above, by stating that the gunpowder in the British service was so inferior to that of the enemy, at the conclusion of the American war, that it was the constant subject of complaint both in the navy and army, and as a fact, that when the fleet was disarmed at the termination of that war, in some of the line of battle ships there were not ten barrels fit for service. Since that time the greatest attention has been paid to the manufacture of gunpowder, both at the royal powder mills, and by the private powder-makers, who contract for the supply of government; so that the British gunpowder, when first made, may be ranked with any foreign powder. But, from the impossibility of procuring seasoned wood to make the powder casks, added to the absolute necessity of keeping an immense quantity of powder in the different depôts for the supply of the navy and army, all of which are situated on the sea or river sides, or in floating magazines, and are consequently much exposed to fogs and damps, and from the impossibility of preventing the damp from injuring the gunpowder in the wooden barrels, even in its short transit from one magazine to another, or from being speedily damaged in the magazines of the men of war, either in those casks or in filled cartridges, notwithstanding every precaution, the gunpowder and the cartridges rapidly go to decay; and the advantages which the service should derive by the superior strength of the gunpowder made by and for government, is in a very great degree lessened, if not totally lost to the nation. Sir William Congreve, clearly makes it appear that between the 1st of January, 1789, and 31st of August, 1810, a period of twenty-one years and eight months, government manufactured at their own mills 407,408 barrels of gunpowder; they purchased also of the gunpowder makers, between the 1st of March, 1794, and 31st of August, 1810, a period of sixteen years and six months, 241,980 barrels, making the total of barrels 649,388. The quantity of powder returned back totally unserviceable, because seasoned wood could not be procured to make the barrels, so as to preserve it at sea, amounted to 137,993 barrels. Between the 1st of July, 1790, and the 31st of August, 1810, the quantity returned from the same cause, requiring the process of remaking, by drying, dusting, and mixing old powder with new, amounted to 189,757 barrels, making the quantity of returned gunpowder, because no means could be devised of preserving it, amount to 327,750 barrels.

This calculation proves, beyond the possibility of doubt, that at no part of the above period could it be asserted, as a fact, that any one ship, after being a length of time at sea, was provided with a sufficient quantity of effective gunpowder.

It is presumed, including all the attendant expenses of drying houses, &c., that gunpowder made by government costs infinitely more than it does at the private mills. But supposing each barrel of powder was to cost 8l. exclusive of copper hoops, sixty thousand barrels, the quantity stated by the Hon. Wellesley Pole to be annually required, would amount to 480,000l. per annum, one-fourth part of which, at the very lowest, may be annually saved by adopting copper barrels.

The following is the usual proportions of ingredients in the powder now manufactured in England and France.

	Saltpetre.	Charcoal.	Sulphur.
Common English powder - -	75	12½	12½
Shooting powder - - - - -	78	12	10
or, - - - - -	76	15	9
Powder for blasting mines and quarries	65	15	20
M. Bouchet's patent powder - -	78	12⅛	9⅛

The shooting powder is glazed by the grains being rubbed one against another, in a barrel: the quantity of saltpetre and charcoal in it is large, in order to ensure its quick action.

Miners' powder is similar to the old mortar powder, and has more sulphur and less saltpetre, because the certainty of its operation is of more consequence than the swiftness.

M. Bouchet's powder is now used by the French government: it is very small, and close grained, so that a litre measure weighs 905 French grammes; whereas, the same measure of the best Dartford powder weighed only 857; the French government now requires this compactness in their powder.

Fire Works.

A variety of compositions are employed for the purpose of giving particular appearances to flame, and to accelerate as well as retard the combustion, of the mixture of saltpetre with combustible matters.

What is denominated brilliant fire, (of which there were several kinds,) although partaking in a great measure of the character of the Chinese fire, differs from it, nevertheless, in an essential particular. Besides the usual substances which enter into the composition of brilliant fire, it is now known, and the fact is sufficiently corroborated, that what is called iron sand by the Chinese, which imparts that particular character to their fire, is no other than cast, crude, or pig iron reduced to the state of fine grains.

The cast iron used for this purpose is old iron pots, which they beat into grains not larger than mustard seed; these they separate into sizes, or numbers, in the manner of assorting shot, by means of sieves.

Both iron filings and granulated cast iron have been used in the rocket composition, not only for honorary rockets, but also

occasionally for signal rockets. To prevent the iron from rusting, some have suggested immersing the grains of iron in melted sulphur, which is almost as injurious, owing to the gradual formation of the sulphate of iron, and others have recommended the use of a few drops of oil, and agitating the filings or grains so as to receive a portion of it.

Of the rockets into the composition of which iron sand enters, there are two, one producing a red, and the other a white fire. The proportions of the different ingredients for such rockets, from 12 to 36 pounds, are as follow:—

For Red Chinese Fire.

Calibres. Pounds.	Saltpetre. Avoir. pounds.	Sulphur. Ounces.	Charcoal. Ounces.	Cast iron. Ounces.
12 to 15	1	3	4	7
18 to 21	1	3	5	7½
24 to 36	1	4	6	8

For White Chinese Fire.

Calibres. Pounds.	Saltpetre. Pounds.	Meal powder. Ounces.	Charcoal. Ounces.	Cast iron. Ounces.
12 to 15	1	12	7½	12
18 to 21	1	11	8	11½
24 to 36	1	11	8½	12

Although the iron is ignited by the combustion of the composition, the combustion of the iron itself does not take place within the tube or only in part, but requires the oxygen of the atmosphere; for the greatest brilliancy of the fire is actually in the air, where the ignited and minutely divided iron is acted upon by the oxygen gas of the atmosphere.

The mixture of the sulphur and iron should be moistened with spirit of wine, as water would rust the iron.

Certain compositions, commonly denominated white fire, are used in cases, and give motion to wheels and the like, the motion is on the rocket principle, and depends on the gaseous products of the inflamed matter acting against the resisting medium, namely, the atmosphere. Chinese fire, however, possesses, in this respect, but little force, and will not turn a wheel; hence, when it is used in rotatory works, it must be accompanied with two or more jets or cases of white fire.

With regard to the preparations of Chinese fire, which are said to surpass even those of the Chinese, the following are the most perfect:—

Composition of Chinese Fire for calibres under ten-twelfths of an Inch.—16 ounces each of meal-powder and saltpetre, 4 each of sulphur and charcoal, and 14 of cast-iron.

Another.—16 ounces of meal-powder, 3 each of sulphur and charcoal, and 7 of cast-iron.

Another, for Palm-Trees and Cascades.—12 ounces of saltpetre, 16 of meal-powder, 8 of sulphur, 4 of charcoal, and 10 of cast-iron.

Another, White Fire, for calibres of eight-twelfths and ten-twelfths of an Inch.—8 ounces of sulphur, 16 each of meal-powder and saltpetre, and 12 of cast-iron.

Another, for Gerbes of ten and eleven-twelfths and one Inch calibre.—1 ounce each of saltpetre, sulphur, and charcoal, 8 each of meal-powder and cast-iron.

What are denominated fire-jets or fire-spouts, are cases charged solid with particular compositions. These jets have a calibre of one-third of an inch to one inch and a third in interior diame-

ter. They are seven or eight diameters in length, and are charged with the particular composition, driving each charge with twenty blows of a mallet. The first charge is the ordinary fire composition. Fire-jets are calculated for turning as well as for fixed pieces.

Common Fire, for calibres of one-third of an Inch.—16 ounces of meal-powder, and 3 of charcoal.

Common Fire, for calibres of five-twelfths to half an Inch.—16 ounces of meal-powder, and 3¼ of charcoal.

Common Fire, for calibres above half an Inch.—16 ounces of meal-powder, and 4 of charcoal.

Brilliant Fire, for ordinary calibres.—16 ounces of meal-powder, and 4 of filings of iron.

Another, more beautiful.—16 ounces of meal-powder, and 4 of filings of steel.

Another, more brilliant, for any calibre.—18 ounces of meal-powder, 2 of saltpetre, and 5 of filings of steel.

Brilliant Fire, very clear for any calibre.—16 ounces of meal-powder, and 3 of filings of needles.

Silver Rain, for calibres above two-thirds of an Inch.—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and 4½ of filings of fine steel.

Grand Jessamin, for any calibre.—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and 6 of filings of spring steel.

Small Jessamin, for any calibre.—16 ounces of meal-powder, 1 each of saltpetre and sulphur, and 5 of filings of steel.

White Fire, for any calibre.—16 ounces of meal-powder, 8 of saltpetre, and 2 of sulphur.

White Fire, for any calibre.—16 ounces of meal-powder, and 3 of sulphur.

Blue Fire, for Parasols and cascades.—8 ounces of meal-powder, 4 of saltpetre, and 6 each of sulphur and zinc.

Another Blue Fire, for calibres of half an Inch and upwards.—8 ounces of saltpetre, 4 each of meal-powder and sulphur, and 17 of zinc.

The cases charged with these compositions are only employed for furnishing the centre of some pieces, the movement of which depends on other cases; as these, having no projectile force, would not produce motion.

Blue Fire, for any calibre.—16 ounces of meal-powder, 2 of saltpetre, and 8 of sulphur.

Radiant Fire, for any calibre.—16 ounces of meal-powder, and 3 of pin-dust.

Green Fire for any calibre.—16 ounces of meal-powder, and 3⅛th of filings of copper.

Aurora Fire, for any calibre.—16 ounces of meal-powder, 3⅛th of brass powder.

Italian Roses, or fixed Stars.—2 ounces of meal-powder, 4 of saltpetre, and 1 of sulphur.

Another for the same.—12 ounces of meal-powder, 16 of saltpetre, 10 of sulphur, and 1 of crude antimony.

The forms which may be given to the flame of gunpowder, or to the substances which compose it, either by increasing or retarding its combustion, or by changing the appearance of the flame, giving it the form of jets, stars, rain, &c. are so numerous, that a knowledge of these changes and variations is considered highly important to the practical fire-worker. For instance, in the composition of fire-works, oak charcoal, and pit-coal, will give the appearance of rain.

The following is one of the formula:—8 ounces of saltpetre, 4 of sulphur, 16 of meal-powder, 2½ each of oak charcoal and pit-coal.

Another composition, intended for the same purpose, is similar to the Chinese fire, but contains a large proportion of powdered cast-iron.

In the spur fire, so called from its spark resembling the round of a spur, used principally in theatres, the particular appearance which characterizes it from other fires, is imparted to it simply by lamp-black.

The composition is:—4½ pounds of saltpetre, 2 of sulphur, and 1½ of lamp-black.

The red fire, used for theatrical purposes, is made from forty parts of dry nitrate of strontian, thirteen parts of finely-powdered sulphur, five parts of chlorate, or oxymuriate of potash, and four parts of sulphuret of antimony, mixed intimately in a mortar; but the chlorate of potasse must be powdered separately. A little orpiment is sometimes added, and if the fire should burn dim, a small quantity of powdered charcoal is added.

The portable fire-works made in miniature, and exhibited in rooms, or close apartments, are much of the same nature as already described.

Other compositions are made, as serpents, crackers, stars, Roman-candles, rocket-stars, variously coloured fire-rains, white, blue, and yellow illumination, port-fires, &c. which show that the colour and appearance of flame may be modified with almost as many variations as the mixture of pigments employed by the painters.

Bengal lights, although in some recipes orpiment is added, owe their particular characteristic to the presence of antimony. The preparation was kept secret for some time.

The true formula is the following:—3 pounds of saltpetre, 13¾ ounces of sulphur, and 7½ of sulphuret of antimony.

The composition is not used in cases, but is put into earthen vessels, usually shallow, and as broad as they are high. A small quantity of meal-powder is scattered over the surface, and a match is inserted. Pots, thus prepared, are covered with paper or parchment, to prevent the access of moisture, which is removed before the composition is inflamed.

Blue lights, or blue fire, is a preparation in which zinc and sulphur, or sulphur alone, are used. The particular colour is communicated by the zinc and sulphur.

The most perfect blue light is made as follows:—4 parts of meal-powder, 2 (or 8) of saltpetre, 3 (or 4) of sulphur, and 3 (or 17) of zinc filings.

The representation of cascades and parasols, are made with the above or similar compositions, as already noticed, but the ordinary blue light, used sometimes for signals, and adapted to any calibre of a case, is composed of sixteen parts of meal-powder, two parts of saltpetre, and eight parts of sulphur.

Brass is added in the sparkling and green fire. To prepare which, about three parts of brass filings are mixed with sixteen parts of meal-powder.

The amber lights are constituted of amber and meal-powder, in the proportion of three of the former to nine of the latter.

Verdigris and antimony are frequently joined to produce a green colour.

For the green match for ciphers, devices, and decorations, one pound of sulphur is melted, one ounce of powdered verdigris, and half an ounce of crude antimony are then added: cotton, loosely twisted, is soaked in the mixture when melted. When used, it is fastened to wire, and the wire is bent into the shape required. It is primed with a mixture of meal-powder and spirit of wine, and a quick match is tied along the whole length, so that the fire may communicate to every part at the same time.

A strong decoction of jujubes treated with sulphur, imparts to cotton the property of burning with a violet-coloured flame.

Sulphur alone, or zinc and sulphur, gives a blue device.

More attention has been paid to rocket compositions than to any other. The formulæ are, therefore, numerous on the subject.

The following are given as the most approved:—

For Summer.—17 ounces of saltpetre, 3½ of sulphur, 1½ of meal-powder, and 8 of oak charcoal: or, 16 ounces of saltpetre, 4 of sulphur, and 7½ of charcoal.

For Winter.—17 ounces of saltpetre, 3 of sulphur, 4 of meal-powder, and 8 of oak charcoal: or, 44 ounces of saltpetre, 4 of sulphur, and 16 of charcoal: or, 16 of saltpetre, 2½ of sulphur, and 6 of charcoal: or, 3 ounces of sulphur, 20 of saltpetre, and 8½ of charcoal.

For rockets of honour, either cast-iron or antimony are used.

The Chinese composition is the following:—5 ounces of saltpetre, 1½ of sulphur, 1 of meal-powder, and 2½ each of cast-iron and charcoal. The charcoal is not to be powdered very fine, as the fine dust is not used, except for small works.

M. Bigot's formula, for the same purpose, is:—2 parts of meal-powder, 10 of saltpetre, 3½ of sulphur, 5 of charcoal, and 5 of powdered cast-iron. He has also given another composition, consisting of 16 parts of saltpetre, 4 of sulphur, 9 of charcoal, and 2 of crude antimony.

The composition of the Congreve rockets is supposed to differ from the ordinary kind in many essential particulars: but General de Grave transmitted to Paris a Congreve rocket found on the French coast. The case was made of gray paper, and painted. The largest sort is usually made of sheet iron. The inflammable matter was of a yellowish gray colour, and the sulphur was distinguished with the naked eye. It burnt with a quick flame, and exhaled sulphuric acid gas. The composition was analysed by Gay Lussac, who found it to contain 720 ounces of saltpetre, 16 of charcoal, and 234 of sulphur. Gay Lussac, after determining the proportions, made a composition of a similar kind, and charged a case with it which had the same properties as the English rocket. The proportion of charcoal seems too small.

The art of representing figures in fire, consists in mixing [illegible] with saltpetre, and a little with water, and covering the figure with the composition, after it is fixed in the ground, to coat it with a little powder. When a train is laid to it, and fired at the [illegible] Where dots, or lines are [illegible] the fire will appear in the form of the figure. By [illegible] may be produced [illegible]

[illegible] The [illegible] Chinese [illegible] of the [illegible] of saltpetre, 1 of sulphur, and 1 of charcoal. [illegible] of sulphur, 1 of saltpetre, and 1 of charcoal. [illegible] of saltpetre, 1 of sulphur

Smoke Balls, to drive Men from between Decks, or hollow Casemates.—Melt 4 pounds of pitch and 1 of tallow, in a pan set in a copper of boiling water, and add 10 pounds of corned powder, and 1 of saltpetre. Fill the shell a quarter full with this composition, then put in a little of a mixture of 2 pounds of sulphur with 3 of pit-coal; proceed to fill the shell half full, and then put in more of the sulphur and pit-coal; and the same when the shell is three-quarters filled.

Dr. Mac Culloch, in an excellent paper on the Greek fire, attempts to show that there were two kinds of it; one of which contained saltpetre, and was analogous to the modern rocket, except that it had no projectile force, and required to be thrown by artillery, either mechanical or chemical, like the modern squibs. The other kind of Greek fire was a resinous composition, in which naptha formed a principal ingredient.

The modern carcass is a combination of the two; the nitrous composition being used to fill the body, while its outside is payed over with the resinous composition, or kitt: the approach to the carcass, to extinguish it, is rendered dangerous, by the loaded pistol-barrels which are inserted in the charge, and directed different ways.

Dr. Mac Culloch seems to think that an oil, like naptha, could not be advantageously used in mixture with powder or saltpetre. It appears, however, from the Military Discipline of Gerat Barry, an Irish captain in the Spanish service, in 1634, that for entering breaches, or ships, or to break into an array of pikemen in a narrow place, they then used fire-trunks, for which he gives this receipt.

Six parts of musket powder, 4 of sulphur, 3 of saltpetre, 1 each, of sal ammoniac, pounded glass, and of camphire, 2 of rosin, and a half part of quicksilver, well mixed together, and then beat up with oil of juniper berries, or oil of petroleum, (by which naptha is no doubt meant,) and spirit of wine. The trunks or wooden cases bound round with marline, were charged in alternate layers with this composition and gunpowder; and the quantity of three musket charges of powder was placed at the bottom of the trunk, which was fastened to a pike staff. He says the flame of these trunks will reach twelve feet or more.

Oxymuriate of Potasse.

This salt has been recently named *chlorate of potasse*, as it is produced by passing oxymuriatic acid gas, otherwise called chlorine, through potasse water.

In general the subcarbonate of potasse water is made of American potash, which is purified as much as possible, by allowing it to remain for some days in stone-ware vessels, before pouring it off for use; and it should be of the strength of 30 to 35 of Baumé, according to the temperature of the season. After

the apparatus has been made ready, and the joinings carefully luted, a quantity of muriatic acid is poured into each of the bodies, which is repeated when the oxymuriatic acid gas ceases to come over: and this is continued until the acid is consumed; as the strength of the acid can be known pretty accurately, the two are proportioned to one another by the operator, and he pours no more muriatic acid into the bodies than will produce oxymuriatic acid gas enough to answer this purpose. When all the acid has been added, and the gas has nearly ceased to pass over, heat is applied, but very gradually, and without interruption, till the tubes of communication become heated, and the liquid in the intermediate bottle is discoloured, and augmented in quantity. During the operation, care must be taken to keep the pipes clear of obstruction, and to notice the height of the liquid in the safety pipes, or the operator will be much incommoded by the emission of the chlorine, or oxymuriatic acid gass; the alkaline solution, into which the gas is conveyed, grows at first thick, owing to the silica contained in the potash, which is precipitated as the saturation is effected; afterwards an effervescence takes place, which increases as the operation is continued, and crystals of chlorate or oxymuriate of potash are deposited in brilliant scales. In some laboratories the solution of potash is filtered after the operation has been begun, in order to separate the silica, which is almost wholly deposited at the commencement. This, however, is an inconvenient method, and, in general, it is better to wait till the operation is over, when, after having drained the liquid off the chlorate and the silica, boiling water is poured on them, which is then filtered, and the chlorate or oxymuriate will crystallize as the water cools.

This salt has the property, when mixed with combustibles of decomposing them with a violent detonation. On this account Berthollet proposed to use it in making gunpowder, and a manufactory was begun at Essonne, in France; but the very first attempt at making it cost two persons their lives, the project was immediately abandoned, and has never since been revived. It, however, forms the basis of Mr. Forsyth's percussion powder, which is now employed as a priming for fowling pieces, and of the matches for procuring instantaneous light; it is also used to make oxygen gas.

Javelle Bleaching Liquor.

A manufactory at Javelle sold a particular liquor, which they called Javelle ley, and which had the property of bleaching cloth, by an immersion of some hours only.

The following are the proportions which yielded a liquor similar to Javelle ley: two pounds and a half of common salt, two pounds of sulphuric acid, three quarters of a pound of black manganese, and, in the vessel where the gas is to be condensed, two gallons of water, and five pounds of potash, which

should be dissolved in the water. The Javelle liquor has a somewhat reddish appearance, occasioned by a small quantity of manganese, which either passes in the distillation, because an intermediate vessel is not used, or exists in the potash, most kinds of which contain it.

This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more speedily than the liquor itself; but there is formed a portion of oxymuriate of potash, which is useless for bleaching.

Chlorate, or oxymuriate of potasse, mixed with muriatic acid, and diluted with water, forms an extemporaneous bleaching liquid, of this kind, which may be instantly made; for it is only necessary to put a few grains of the oxymuriate into a tea-spoonful of spirit of salt, and dilute it with water, and it will remove almost all kinds of spots from linen, except those made by oily or greasy substances.

Acetate of Potasse.

This was called, by the medical faculty, *foliated earth of tartar*, and *diuretic salt;* it was formerly made from distilled, or even common vinegar, which rendered it extremely difficult to procure the salt of a pure white colour.

It is now generally made, by dissolving a Troy pound of purified pearl-ash in two pints of water, and pouring into this solution a sufficient quantity of purified pyroligneous acid, until an effervescence is no longer produced; of which, according to Mr. Phillips, it will require about 25½ ounces of the acid ordered by the College of Physicians. They order the liquid to be evaporated until the surface skins over; and these skins, as they form, to be taken off and dried between white filtering paper.

The manufacturers generally filter the liquid twice; first as soon as the acid and alkali are mixed, and then, again, when the liquid is evaporated nearly to the consistence of a syrup, and cooled. They then evaporate the filtered solution, by small portions at a time, in a large pan; and, as the solution skins over, the skins are brought by a spatula to the side of the pan to dry.

When acetate of potasse is made with vinegar, although it is distilled, or with unpurified pyroligneous acid, the alkali should be added to the acid; and it will be necessary, after the skins or exfoliations are procured, to blanch them, by melting them in a gentle heat, adding a little bone-black, then pouring on the cooled mass distilled water, to re-dissolve the salt, replacing the acid which has been driven off by the heat, with some purified acid, and again evaporating the liquid, and separating the exfoliations as they form.

This salt is so apt to grow moist, and even run to water, in the air, or in stoppered bottles, that it should be kept in small well-corked phials, and the corks rosined.

The composition of *acetas kalicus*, according to Berzelius, is K: A-2, and its weight 2,462,000. Dr. Thomson, who crystallized his salt in a vacuum over oil of vitriol, makes it K· A+2 H·, and its weight 14,500; from which, if the water of crystallization be taken, the weight of the dry salt will be 12,230.

Soluble Tartar.

This salt is the *tartarate of potasse* of the theoretical chemists, and present medical faculty.

It is made by dissolving sixteen pounds of purified pearl-ash in sixteen gallons of water, and adding cream of tartar until it no longer produces an effervescence, which will take about thirty-six pounds. The solution is then filtered through paper, boiled to a skin, and then set by to crystallize as it cools.

This is used largely as a medicine: the practising apothecaries frequently do not take the trouble to make it, or pay the price of it, but keep the salts mixed in the proper proportions, and make up the prescriptions with this mixed powder.

This *tartaras kalicus* of Berzelius, is equal to K: T-2, or 2,848,810: Dr. Thomson makes it K· T-, or 14,250, when dry, but the crystals contain two atoms of water of crystallization.

Oxalate of Potasse.

This salt is easily prepared by saturating carbonate of potasse-water with liquid oxalic acid.

It is used to discover the presence of lime in mineral waters, or acid solutions.

Berzelius states the composition of *oxalas kalicus* as K: O-2, and its weight as 2,083,370: Dr. Thomson as K· O-, or 10,500; the crystals retain one atom of water.

Triple Prussiate of Potasse.

This salt was first formed by Dr. Macquer, and called by him *phlogisticated alkali*, and by others *Prussian alkali*. In the old French nomenclature of Lavoisier, it was the *triple prussiate of potasse*. M. Porret calls it *ferruretted chyazate of potasse*, which Dr. Thomson has shortened to *ferro chyazate of potasse*; in the new French nomenclature of Gay Lussac, it is the *hydro-ferro cyanate of potasse*. It is also called the *ferro prussiate of potasse*.

This many and long-named salt is thus made:—Two pounds good pearl-ash, and five of hoofs and horns, are flung into a slightly red-hot iron pot set in a furnace. The mixture is stirred well with a flat iron paddle, and as it calcines, it will gradually assume a pasty form, during which transition it must be kept stirred about without any sparing of manual labour. When the cessation of the fetid animal vapours shows the calcination is finished, the pasty mass is taken out with an iron ladle.

If this were thrown, while hot, into water, some of the prussic acid would be converted into ammonia, and of course the usual product diminished; it is, therefore, allowed to cool, and dissolved in water. The solution is then clarified by filtration or subsidence, and evaporated until, on cooling, yellow crystals of the ferro-prussiate of potash are produced. These crystals are separated, re-dissolved in hot water, and by allowing the so-

lution to cool very slowly, large and very regular crystals will be obtained.

The original method of making triple prussiate of potasse, and which is still used, is, by acting on Prussian blue with pure carbonate of potasse-water. The blue should be previously digested, at a moderate heat, for an hour or two, in its own weight of oil of vitriol, diluted with five times its weight of water; then filtered, and the sulphuric acid thoroughly washed out by hot water. Successive portions of this blue, thus purified from the alumine, are added to the alkaline solution, as long as its colour is destroyed, or while it continues to change from blue to brown. The liquid is filtered, the slight alkaline excess neutralized with acetic acid, then concentrated by evaporation, and allowed slowly to cool and crystallize.

The triple prussiate of potasse is used to ascertain the presence of metals in waters, and acid solutions. Its composition is not settled, as it is uncertain whether the acid itself contains hydrogen, or is merely a combination of one atom of cyanogen with one of iron, or 2 C Az Fe. Indeed the whole theory of Prussian blue, and the substances obtained from it, has, ever since its discovery, been a riddle, which no chemist has been able to solve.

Priming for Percussion Guns.

A variety of experiments have been made, by Lieutenant Schmidt, on the different powders used as priming for percussion guns.

He found a mixture of 100 grains of oxymuriate of potasse, with 12 of sulphur and 10 of charcoal, to be much preferable to either fulminating silver, or fulminating quicksilver, for priming. It is not so liable to accidental explosion, it leaves behind it less acid matter, and does not corrode the iron so rapidly; and, contrary to what takes place with fulminating quicksilver, its explosion is not followed by a deposition of moisture. The facility and certainty of the explosion is the same in both.

A mixture of 100 grains of chlorate of potash, with 42 of saltpetre, 36 of sulphur, and 14 of lycopodium, is not nearly so efficacious as the first; although this is chiefly a consequence of the ordinary construction of the touch-hole. The best method of filling the copper caps is, to mix up the explosive compound into a thick liquid, with any adhesive solution or tincture, and, by means of a hair pencil, to introduce a large drop of this mixture into the bottom of each cap.

Another preparation for the priming powder for percussion guns, is three drams of regulus of antimony, and one dram of oxymuriate of potasse. On account of the corrosive properties of the oxymuriate of potash, it is adviseable to use the smallest possible quantity that will be certain of ignition; the above ingredient, if well compounded from a percussion powder, will fire with the greatest certainty.

One great objection to the stronger preparations for priming, is the great and sudden corrosion produced after firing; so violent is this, that should the interval between firing much exceed an hour, the touch-hole is not unfrequently completely closed by a strong rust.

SODA, OR MINERAL ALKALI.

This fixed alkali was confounded with potasse, until Margraaf pointed out the difference. It was distinguished by him as the *alkali of common salt;* on the first introduction of the significant nomenclature, it was called *natron*, but the French chemists altered this to *soda*, by which it is called in South Europe and the British Islands; but the Northern nations retain Bergmann's generic name of *natron* or *natrum*. It has also been called *fossil alkali*, which Dr. Pearson contracted into *fos-alkali*.

Pure soda is obtained by burning sodium in oxygen gas, but is not used.

Soda or natrum is, according to Berzelius, Na^2, equal to 781,840; but Thomson makes it only Na or 4,000.

Kelp.

This is an impure carbonate of soda, which is made from plants which grow on the sea-shores, and generally from those growing between high and low water-marks. All shores are not equally adapted for the production of these plants. On such as are exposed to the ocean, the rolling of the waves, and the fury of the tempests, prevent the plants from taking root. They thrive best in sheltered bays, where the retreat of the tide leaves an extensive surface uncovered, and where the bottom is composed of stones or rocks, to fasten their roots.

Only the plant called *tangle*, and some others which adhere with great force to the rocks, are found to grow on exposed situations. But these are always within the low water-mark of ordinary tides, and can only be procured at the very low ebb of spring tides. They are, however, so strong and substantial, that they will amply reward the labourer for his trouble.

Though the spring be the best season for making kelp, yet, owing to other avocations at that season, it is seldom made except during summer. To prepare the materials for making kelp, the sea-weeds are dried in the same way that hay is made, taking care to let it get as little rain as possible. When dry, it is coiled or stacked up for burning, and the stacks so formed as to exclude rain.

The breadth of the kilns for burning the weeds ought always to be twenty-eight inches. If the kilns be two or three inches narrower, they will not contain a sufficient quantity of stuff to raise a proper heat. Making them wider is still worse; for then some of the stuff in the middle will not be half burnt. With the assigned breadth, they may be extended in length, as far as the quantity of stuff to be burnt may require.

The kilns are commonly made of various lengths, from eight to eighteen feet, and about two and a half feet high. They

are built of stone, and placed sideways to the quarter from which the wind commonly blows. The windward side is covered with green turf; and if the wind be high, it is covered all round with turf as occasion may require.

Some dig a round hole in the earth, and line it with stone. But a considerable proportion of the stuff in such a kiln, remains not completely burnt, and what is left in that state yields no alkali. It is indifferent what kind of fuel is used, provided it be properly set. If it be wood or heath, it is set on end, so as to fill the whole kiln from one end to the other. If heath is used, the top is always put undermost; and the strongest sort that can be got is preferred.

The kiln being thus filled with fuel, some of the driest ware is spread lightly over it, until the whole be covered. Then, if the day appears good, the fire is applied at the end which is farthest from the wind. It is, then, lightly and constantly supplied as it needs, with fresh ware, thrown by the hand, or a pitch-fork, upon every red hole that appears. In calm weather, when it burns slowly, it is lightly fed, that it may get air. If the weather be very calm, the turf-cover is removed from both sides of the kiln. If there be a slight wind, the windward side, at least, is covered; and if the wind should rise, both sides are instantly covered; and again, if high, the covering is doubled as circumstances may require.

During the whole process, every hole that appears is quickly and attentively filled with fresh materials, until the whole of the sea ware is burnt. Then the feeding should stop all at once; and every hole that appears is filled with a fork, from the thickest and least burned portions, until the stuff is seen to soften or melt at the stones of the kiln. This is the most critical period of the whole process, for sometimes, in cold weather, it is apt to freeze or harden on a sudden: to prevent this, it is instantly wrought in the following manner.

The instruments used for this purpose are strong, narrow clads or clatts, with long handles of iron. Before these are applied to the materials, they are previously heated over the flame; for a cold body introduced among the stuff, at this stage of the process, causes what is already prepared or melted, to fly in the face of the workman, or scatter about.

The operation is begun at the corner farthest from the wind, by pressing down a little of the unmelted stuff to the bottom of one of the holes nearest to the stones. If it appear to boil, soften, or melt, more stuff is added, and pressed down as before.

It must then be wrought backwards and forwards, until the mass is brought to a proper consistency. When that is done, this portion should be dropped, and another portion contiguous

[illegible] taken and wrought in the same manner, until [illegible] finished. Sometimes a portion of the kelp will [illegible] congealed on the sides of the kiln: this is taken off [illegible] working, and mixed with the rest, but in such proportion as not to cool the part that is preparing.

But if, when this operation is begun, the materials still continue hard and dry, they are allowed to burn a little longer. When again tried, if they still remain dry like ashes, a little common salt, sprinkled over the whole of the stuff, adds greatly to the force of the fire. If it still continues obstinate, more salt is added: and, if the weather be calm and warm, the kiln is allowed little or no covering on its sides, unless its contents threaten to congeal.

If the salt has not the desired effect, which seldom happens, a little saltpetre is mixed with it, which causes it to burn vigorously: or, if it be very dull, a little flowers of brimstone is added to produce the same effect.

This disagreeable double toil seldom occurs, except in bad weather, or when rain got at the ware while it was drying. Ware that is dirty or soiled, from having grown in confined muddy bays, is also liable to this accident.

When a new burning commences, if much dust and ashes remain from a former burning, the smaller parts are fed into the kiln with the fresh ware or wrack, after it has begun to burn vigorously; and towards the close of the process the largest and hardest parts are placed in a row along the centre of the kiln from end to end. Thus the heat brings the whole into fusion, so as to form kelp. After the kelp is made, it is carefully excluded from air and moisture.

It is esteemed of good quality when, on breaking a piece, it is hard, solid, and has some reddish and light blue shades running through it. When it has none of its peculiar salt taste it is unfit for making ley, though it may be of use to glass-makers.

By dissolving a little of it in water, it can be ascertained whether it is adulterated by sand, mortar, or stones: though it is impossible to make kelp free of some sand and stones, in the ordinary ways of preparing it.

According to Lawson, 1000 pounds of *Mull's Cunnamara kelp* contains only 3 pounds 875 of pure soda, and the same quantity of *Strand-ved kelp* only 1 pound and one-fourth.

Chaptal says the *blanquette* or *soude of Alicante*, which is made from various plants growing wild on the sea-shore, as, salicornia Europæa, salsola tragus, atriplex portulacoides, salsoli kali, and thrift, contains only 3 to 8 pounds of carbonate of soda in 100.

The *varech*, or *soude of Normandy*, made from sea-weeds, contains scarcely any carbonate of soda, but is a mixture of much of the sulphates of soda and potasse, and of the muriates of the same alkalies, with a little of the iodure of potassium.

Barilla.

The best kind of carbonate of soda is called barilla, from an herb of the same name in Spain that produces it, the mesembryanthemum nodiflorum.

The carbonate of soda made of this plant, makes the best soap, the finest glass, and is the best for bleaching of any other.

Whether or not it would grow in England is not known, as it has, perhaps, never been tried on a large scale; but it would be a considerable improvement where fixed alkalies of all kinds are so valuable a commodity, and so much wanted; for it grows on the same ground with corn of any kind, to which it does no harm, as it is a small annual herb, that does not spread till the corn is ripe or off the ground.

There is another kind of barilla imported from Alexandria, commonly called *rochetta*, procured from the mesembryanthemum Copticum. Some prefer this to the Spanish barilla, es pecially for making glass.

These two species of barilla contain about 25 pounds to 40 of carbonate of soda in 100 pounds.

The *salicor*, or *soude of Narbonne*, is produced from the salicornia annua, cultivated round about Narbonne: this contains about 14 or fifteen pounds of carbonate of soda in 100 of salicor. An English acre and a quarter yields only a ton of salicor, which produces about 100 pounds of the alkali. The plant grows wild on the shores of England.

Natrum or Trona.

This is imported from Egypt and Africa, in solid masses. They are found on the hedges of pools dried by the summer's sun.

The same kind of mineral alkali is also obtained by evaporating the water of certain lakes in Hungary and America.

This salt differs from kelp and barilla as being principally formed of the sesqui-carbonate of soda.

Carbonate of Soda, or Mineral Alkali.

This salt is the *mild mineral alkali* of the late chemists, and the *sodæ sub-carbonas* of the medical faculty, and is ordered by the College of Physicians to be made by dissolving Spanish barilla in four times its weight of water, filtering, evaporating to half its bulk, and setting it by to crystallize; but this process is too expensive for the manufacturers.

Le Blanc and Dize's process is, to mix 180 pounds each of dry Glauber's salt and chalk with 110 of charcoal, to grind them together, to heat the powder in the side chamber of a reverberatory, stirring the mass every quarter of an hour. The mass becomes pasty, it is then drawn out by hoes into iron

pots: the produce is about 300 pounds, containing about 100 of pure carbonate of soda. Six workmen can make ten parcels, or nearly a ton and a half in twenty-four hours.

Several other processes have been invented, in some of which the spent bark of the tanners have been used instead of charcoal.

Carbonate of soda is also obtained as a secondary product in the manufacturing of mineral yellow from lead.

Several attempts have been made to procure it from common salt; by calcining the salt with charcoal, but without success.

In some manufactories wood vinegar is employed to decompose Glauber's salt.

The process employed is extremely simple. It consists in boiling for a given time, a solution of Glauber's salt with a solution of acetate of lime, prepared with pyroligneous acid. In this operation the sulphuric acid leaves the soda to attach itself to the lime, and at the same time the acetic acid combines with the soda, and forms an acetate of soda: the latter salt being very soluble remains in solution, whilst the sulphate of lime, which is difficult of solution is precipitated.

When the operation is considered as finished, the liquor is left to cool, filtered, evaporated to dryness, and the residuum calcined in a furnace made for the purpose; and when the acetate is entirely decomposed, nothing remains but a white substance, the solution of which, in water, needs only to be evaporated to a suitable point to furnish very fine crystals of carbonate of soda.

When the idea of decomposing the sulphate of soda with the vinegar of wood was first conceived, it was thought that this acid might be used unrectified; but it was soon found that the soda obtained from it was not pure, and that, to procure it in the state desired, it was necessary to have recourse to fresh operations, which, of course, rendered the process more complex.

Mr. Hodson has bestowed much attention on this subject, and took out letters patent for the following process.

Having prepared three hundred weight of well-burnt lime, it is slaked with a strong brine, and sprinkled with it until the salt appears to be accumulating on its surface. The lime thus slaked and saturated with salt, must be spread into thin layers, until the evaporation is completed, and then thrown into a reverberating furnace, with a chamber on the side. To this afterwards must be added, three hundred weight of salt, or rock salt in a shelly state, and the whole melted with a strong heat. When this is effected, two hundred weight of gypsum, and two hundred weight of sal enixum, are to be introduced, and

by means of repeated stirring with a hoe, the different materials must be as generally, and as uniformly, distributed as possible.

Two spades full of small coal, coke, or charcoal, must next be thrown into the furnace; and by means of stirring as before, intimately united with the whole mass. This must be repeated at intervals of the space of one quarter of an hour, until two hundred weight of charcoal be consumed; if coal be used, until three hundred weight; if small coal, until four hundred weight be consumed.

The process must then be continued without any farther admixture, with a strong heat, for three or four hours, or more, according to the degree of purity which it is designed the ash should possess. After which the fluid mass is to be extracted by means of the hoe, and when cold, broke up into lumps for use.

In order to obtain mineral alkali from the natural salt of kelp, from soda, and from the residuum of spirit of salt, having previously reduced either of these articles into lumps of about two pounds weight each, about ten hundred weight are thrown into the furnace, with four hundred weight of gypsum, or four hundred weight of soapers' waste. Afterwards, two hundred weight of charcoal are introduced, at intervals, of the space of one quarter of an hour each, and the mass must be continued to be stirred with the rake until the decomposition is effected, which will happen in about ten hours, computing from the commencement of the process.

To obtain mineral alkali from the neutral salts of natron and sal enixum, five hundred weight of natron, or of sal enixum, are thrown into the furnace, with four hundred weight of gypsum, or four hundred weight of soapers' waste. To these are to be added two hundred weight of black ashes, or four hundred weight of salts obtained by evaporation from soapers' leys; all which materials being well united together, two hundred weight of charcoal are added, at intervals, of the space of one quarter of an hour each, and the process continued for about ten hours, computing as before, from the commencement of it.

In obtaining mineral alkali from black ashes, or other salts obtained from soapers' leys, five hundred weight of black ashes, or nine hundred weight of uncalcined salts, are put into the furnace, together with four hundred weight of gypsum, or of soapers' waste. When these materials are completely fluxed, two spades full of charcoal are added, at intervals, of the space of one quarter of an hour each, until two hundred weight of it are introduced. The materials are to be well united by means of the rake, and to remain in the furnace for about eight hours, computing from the commencement of the progress.

Dr. Thomson found that although carbonate of soda is sold in beautiful crystals seven or eight inches long, all the specimens he could procure contained sulphate of soda, and generally in the proportion of two pound in a Cwt. He could not entirely separate this sulphate even by twelve careful crystallizations.

Carbonas natricus, according to Berzelius, is Na: C: ^{2} + 20 (H·H) equal to 3,597,770. Thomson makes it only Na·C: + 10 H·, equal to 18,000, which is the same in effect.

Sesqui Carbonate of Soda

Is obtained, by exposing carbonate of soda water to an atmosphere, or current of carbonic acid gas, as in making bi-carbonate of potasse.

It may be considered as a combination of an atom of carbonate of soda with one of bi-carbonate of soda, or as composed of two atoms of soda with three of carbonic acid and four of water.

It is the *sodæ carbonas* of the medical faculty, and is sold for making soda water.

Bi-Carbonate of Soda.

This is made by forcing carbonic acid gas into strong carbonate of soda water: the crystals cannot be dried, for the least heat drives off a part of the carbonic acid, and converts them into sesqui carbonate of soda.

Carbonate of Soda Water

Is obtained by dissolving carbonate of soda in distilled water.

It is used to discover the presence of lime in mineral waters, and acid solutions containing it. Henry advises it to be kept of the specific gravity of 1·110, as it will then neutralize half its measure of either sulphuric acid at 1·135, of nitric acid at 1·143, or of muriatic acid at 1·074.

Caustic Soda.

This is the *hydrate of soda* of the theoretical chemists, and is prepared from carbonate of soda and quick-lime, in the same manner as the hydrate of potasse.

Caustic Soda Water.

This is made from carbonate of soda, by abstracting the carbonic acid by means of lime, and according to Meyer, substituting in its place the principle of causticity. The manipulation is the same as with potasse.

As almost the only use made of it in laboratories is in examining mineral waters, Dr. Henry advises it to be kept of the specific gravity 1·070; when it will be of the same effective strength as carbonate of soda water at 1·110.

Double Soda Water.

This common summer beverage is prepared by dissolving carbonate of soda in water, two avoirdupois ounces to a wine gallon, and forcing carbonic acid gas into the solution, by the apparatus described under carbonic acid water.

The manufacturers call water impregnated only with carbonic acid gas, *single soda water.*

Glauber's Salt.

This salt is found native in some countries; but in England it is generally made from the residue left in making Glauber's spirit of salt, by saturating the superfluous acid, if necessary, by the addition of soda or lime.

It is also obtained, as a secondary product, in the manufacture of sal ammoniac, from sulphate of ammonia.

The salt is purified, and rendered fit for the market, by solution in water, evaporation, and crystallization. As it falls to powder in the air, a vessel, or layer, of water is usually kept in the vessel in which this salt is stored.

Glauber's salt was much used as a purgative, but Epsom salt is now generally preferred by those who are free agents, so that it is now seldom used, except by the parish poor and plantation slaves. It is also used in glass-making.

The crystals contain no less than ten atoms of water, to one each of acid and alkali, according to Thomson, or 55 parts in 100.

Cubic Nitre.

This is the *nitrate of soda* of theorists. It is obtainable by saturating the mother waters of the saltpetre workers with carbonate of soda, instead of wood-ashes; or by saturating carbonate of soda with nitric acid, and crystallization.

Proust recommends it to the fire-workers, as an economical substitute for saltpetre, burning three times as long.

Common Salt.

This is the *muriate of soda* of the old French nomenclature; the *chloride of sodium* of the newest French nomenclature; and the *murias natricus* of Berzelius, and the northern nations.

Common salt may be distinguished into three kinds, viz. 1, rock or native salt; 2, bay-salt; and, 3, white salt; the two former being of a gray colour.

Rock-salt, or native salt, is dug out of the earth, and has not undergone any artificial preparation. Under bay-salt may be ranked all kinds of common salt extracted from the water, in which it is dissolved, by means of the sun's heat and the operation of the air; whether the water, from which it is extracted, be sea-water, or natural brine drawn from wells and springs, or salt water stagnating in ponds and lakes. White salt, or boiled salt, includes all kinds of common salt extracted by boiling from the water in which it was dissolved.

Rock-salt is dug at Namptwich, in Cheshire, and many other places. As it forms very thick beds, the miners use, in general, a peculiar kind of excavation, different from that of the pursuit of metallic veins by galleries. In fact, the mine is a

hollow parabolic conoid, with a narrow entrance by a well at the top.

Fig. 111, represents a section of the salt-mine at Vissehna, on the south-west of the Carpathian mountains, where the bed of salt, which is covered with several strata of clay and sand, has been already penetrated to the depth of about six hundred feet; it contains within it thin veins of the same black fat bituminous clay, containing sulphate of lime, that forms the immediate covering of the bed of salt.

A, the shaft by which it is drawn out.

B, the shaft through which the workmen pass up and down, by means of a ladder.

C, a shaft that conducts the rain-water into the gallery, *e*.

D, a shaft that conducts the rain-water into the drain, *f*.

E, two circular galleries surrounding the shafts, *a* and *c*, to collect the water that drains through the over-lying strata of clay, and conduct it into the drain, *f*.

F, a drain to carry off the water.

G, the conoid space from whence the salt has been worked.

H, pieces of timber driven into the bed of salt, and supporting all the wood work of the shafts: these timbers have sheep-skins nailed on them to preserve them from wet.

I, bags in which the salt is drawn up to dry.

K, cuts in the bed for extracting the salt in oblong squares.

L, blocks of salt ready to be drawn up.

Rock-salt, ground, is used in many countries; but in England, and some other kingdoms, the revenue laws prohibit its use, except in particular cases, under very severe penalties.

Bay-salt of every kind is prepared without artificial heat, and by only exposing the brine, in shallow basins of clay, to the action of the sun and air, by which in proportion to the strength of the brine, and to the different temperature of climate and season, the salt crystallizes spontaneously, and is generally in the form of hollow square pyramids, or hoppers, formed of cubes.

The basins in which bay-salt is prepared, consist of two parts:—1, a large reservoir, which generally communicates with the sea by means of a sluice. In this the salt water is kept for some days, in order to settle and become quite clear before it is let into the proper brine-pits.

2. The brine-pits are a number of very shallow basins, only a few inches deep, with raised paths between them for the workmen to let in the salt-water, and rake out the crystals of salt as they form. These basins communicate with one another by cuts through the paths, which are stopped with a ridge of clay.

Though salt is made in warm climates with the greatest ease, and at the least expense, by the heat of the sun, after the methods already described, yet, in several countries, where bay-salt might be conveniently made, they prepare all their salt by means of fires.

An erroneous opinion long prevailed in England, that the heat of the sun was not sufficiently intense, even in the summer season, to reduce sea water, or brine, into bay-salt. And all arguments would probably have been insufficient to remove this pre-

Fig. m.

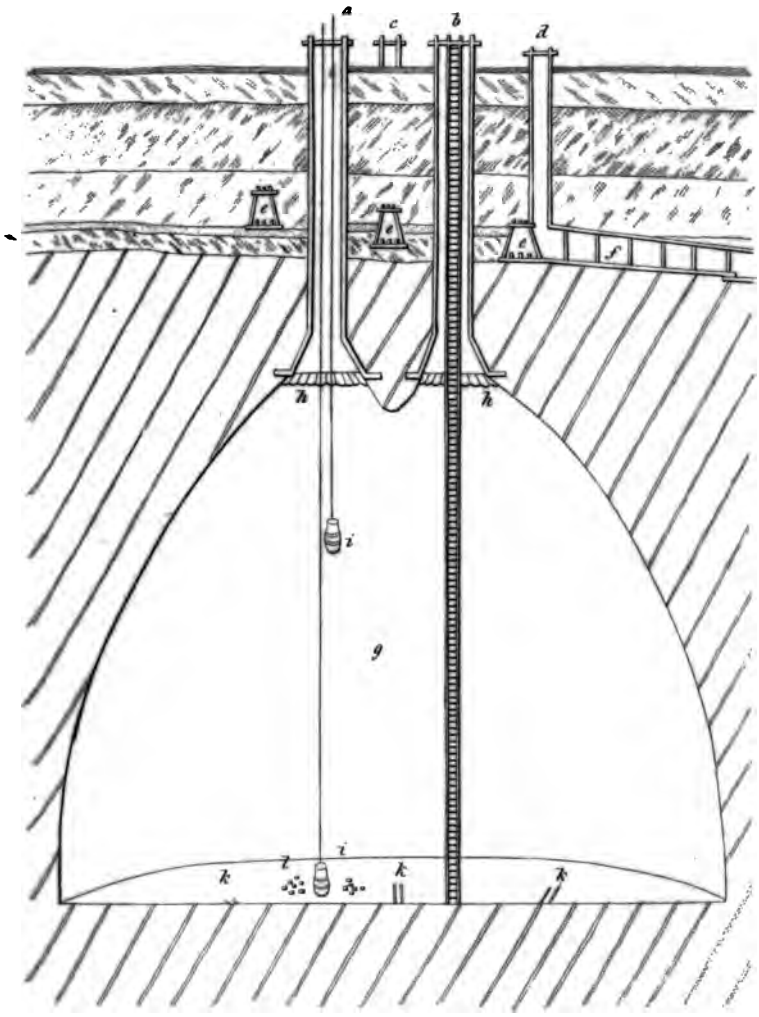

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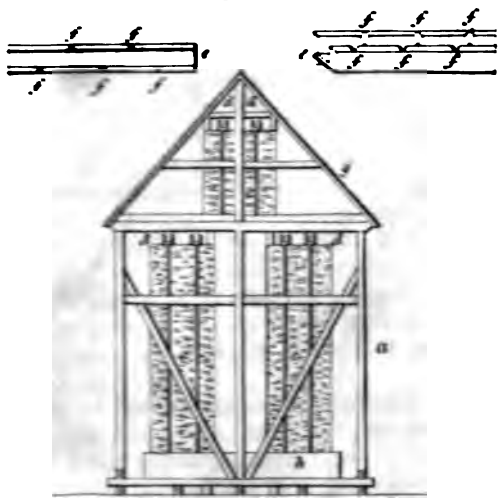
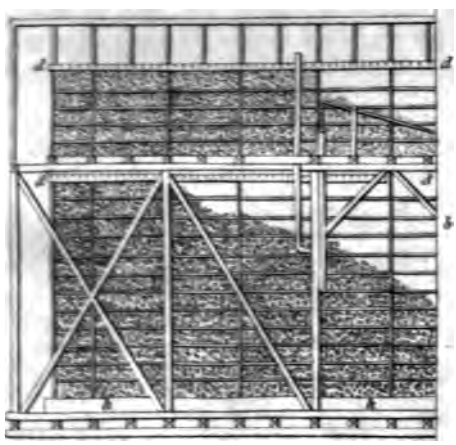
Fig 112





judice from the English, had not the contrary been fully proved by experiments, which were first accidentally made in Hampshire. However, the method of making salt by boiling still continues to be practised in Britain: as the salt so prepared is preferable to bay salt for table use; and, when prepared after a particular manner, is fully equal, or preferable, to common bay salt, even for curing provisions.

The natural brine-springs, and especially the water of the sea, being very weak, a method has been invented to evaporate part of the water without the expense of fuel, by causing it to present a large surface to the air. The brine-pits, used in making bay-salt, necessarily require a large extent of level ground; but graduating houses are best adapted for mountainous situations, a place being chosen, if possible, where there is usually a strong current of air.

These graduating houses are mere carcasses of buildings, filled with thin piles of fagots, like a wall: but sometimes they are filled with a number of ropes hanging down from the rafters. The water being distributed uniformly over these piles of fagots, or ropes, by means of troughs; is exposed in a very thin surface to the action of the air, and thus evaporates quickly.

The graduating houses are covered with a roof, and are not more than ten or twelve feet thick, but often twelve or sixteen hundred feet long; the broad side being opposed to the prevailing winds. It is frequently necessary to pump up the brine twenty times or more to bring it to the required degree of strength. Cool dry winds are most favourable to the evaporation, while damp, dull, and foggy weather, sometimes even renders the brine weaker.

Fig. 112, represents a graduating house.
A, the transverse section of the building.
B, longitudinal section.
C, fagots of thorns, piled up in two tiers below and one above.
D, wooden troughs, to distribute the water over the fagots.
E, plan and perspective view of the troughs.
F, notches through which the water runs out, in slender streams, on the fagots.
G, roof, covered with tiles, laid so as to keep out the rain, but admit a free circulation of air between them.
H, cistern receiving the water.

White salt, as it is prepared from various saline liquors, may be distinguished into the following kinds: 1, marine boiled salt, which is extracted from sea water by boiling; 2, brine, or fountain salt, prepared by boiling from natural brine, whether of ponds or springs; 3, that prepared from sea water, or any other kind of salt water, first heightened into a strong brine, either by the heat of the sun and the operation of the air, or by evaporation, accelerated by mechanical means; 4, that prepared from a strong brine or lixivium drawn from earths, sands, or stones,

impregnated with common salt; 5, refined rock-salt, which is boiled from a solution of fossil salt in sea water, or any other kind of salt water, or pure water; 6, lastly, *salt upon salt*, which is bay-salt dissolved in sea water, or any other salt water, and then boiled into white salt; and, under these heads, may be ranked the several kinds of white salt now in use.

The salt boilers, and particularly those who prepare brine salt, have long been accustomed to make use of various substances, which they call additions or seasonings, and mix them with the brine while it is boiling, either when they first observe the salt begin to form, or else afterwards, during the time of granulation. These additions they use for various purposes. First, to make the salt grain better, or more quickly form into crystals; secondly, to make it of a small fine grain; thirdly, to make it of a large, firm, and hard grain, and less apt to imbibe the moisture of the air; fourthly, to render it more pure; and, lastly, to make it stronger, and fitter for preserving provisions.

These additions are wheat flour, resin, tallow, new ale, stale beer, bottoms or lees of ale and beer, wine lees, and alum. Wheat flour and resin are used for the property they possess of giving the salt a small grain. Butter, tallow, and other unctuous bodies, are commonly applied, as they are said to make the brine crystallize more readily; for which end, some salt boilers more particularly prefer the fat of dogs: but others have little to plead for their using these substances but immemorial custom: how far they have the effects ascribed to them, can only be determined by experiments; as several boilers, who formerly used them, now find they can make as good salt without them. Wine lees, new ale, stale ale, the lees of ale and beer, are now generally rejected by the marine salt boilers, except in the west of England, where the briners who use them affirm that they raise a large grain, and make their salt more hard and firm; and some say, that they make it crystallize more readily. Hoffman prefers the strongest ale; and Plott assures us, that it makes the salt of a larger or smaller grain, according to the degree of its staleness. The only good effects that fermented liquors can have as an addition, are probably owing to their acid spirit, which may correct the alkaline salts of the brine, and so render the common salt more dry and hard, and less apt to dissolve in moisture. If, therefore, it should be thought necessary to use any of these additions, in order to correct the alkaline quality of the brine, stale ale, or Rhenish wine, ought to be chosen, as new ale contains but little acid.

Alum is an addition long known and used in Cheshire, together with butter, to make the salt precipitate from some sorts of brine, as we are assured, by Dr. Leigh, in his Natural History of Lancashire, Cheshire, &c. who first taught the Cheshire salt-

boilers the art of refining rock-salt. As the bad properties of their salt proceeded from hard boiling, they found every method ineffectual till they had recourse to a more mild and gentle heat. And as alum has been long disused among them, it is not likely that they found any extraordinary benefit from it, otherwise they would scarcely have neglected it, and continued the use of butter. Lowndes endeavoured to revive its use, asserting, that brine salt had always two main defects, flakyness and softness; and, to remedy these imperfections, he tried alum, which fully answered every thing he proposed, for it restored the salt to its natural cubical shoot, and gave it a proper hardness; nor had it any bad effect whatever. Neither does it here seem wanted, for the grains of common salt were always sufficiently hard, and of their natural figure, large size, and no ways disposed to run by the moisture of the air, if formed by a gentle heat, and perfectly free from heterogeneous mixtures: so that the goodness of Lowndes' salt did not seem owing to the alum, with which it was mixed, but chiefly to the gentle heat used in its preparation.

The Dutch, who have long shown the greatest skill and dexterity in the art of boiling salt, make use of another addition, which they esteem the greatest secret of their art. This is whey, kept several years till it is extremely acid; which has been long held in great esteem by the Dutch, for the good effects it has on their salt, which it renders stronger, more durable, and fitter to preserve herrings and other provisions.

A decided preference having been given to foreign salt prepared in warm climates, by the spontaneous evaporation of sea water, as a preserver of animal food; and great quantities of it are imported into Great Britain; Dr. Henry, therefore, thought it of importance to determine whether this preference was well founded; and if British manufactured salt was really inferior to foreign salt, to ascertain, as the basis of all attempts towards its improvement, in what this inferiority precisely consists.

Cheshire stoved salt, or lump salt, is made from brine, by a boiling heat (226° Fahr. in fully saturated brine,) until only so much water is left as is barely sufficient to cover the small flaky crystals that have fallen to the bottom of the boiler. The salt is then put into conical wicker baskets, and after being drained, is dried in stoves where it loses about one-seventh of its weight.

Cheshire common salt is made from brine, boiled until it is brought to the point of saturation, and the evaporation finished by a heat of 160° or 170° Fahr. It is in quadrangular hoppers, close and hard in their texture; it is drained, but not stoved.

Cheshire large grained flaky salt is made from brine, evaporated at a heat of 130° or 140° Fahr. It is rather harder than common salt, and approaches to a cubical form.

Cheshire large grained or fishery salt is made from brine, evaporated at a heat of only 100° or 110° Fahr. The process lasts for seven, eight, or even ten days, and the salt forms in large and nearly cubical crystals.

Stoved salt is sufficient for domestic uses; common salt is adapted for striking and salting provisions not intended for sea voyages or warm climates; for which purposes the large grained or fishery salt is peculiarly fit.

On the first application of heat to the brine, a deposite is formed, which is either removed by skimming, or allowed to subside along with the salt first formed, and then raked out. Some brines scarcely require any of this clearing of the pan. Some part, however, sticks to the bottom, and becomes very hard, so that the pan scale (as it is called) must be removed by violence once in three or four weeks.

In Scotland, the sea water is evaporated from first to last by a boiling heat, so that the salt produced approaches to the character of stoved salt: but in some places, the fires being slackened between Saturday and Monday, the crystals are considerably increased in size, and the salt is called Sunday salt.

At Lymington, the sea water is spontaneously evaporated in shallow pits to one-sixth of its bulk before it is brought into the boilers, where the remainder of the water is entirely evaporated, and the whole mass of salt taken out at once, and removed into troughs with holes in the bottoms, through which the bittern or bitter liquor drains into pits. Under the troughs, and in a line with the holes, are fixed stakes, on which a portion of salt crystallizes. These salt cats (as they are called,) weigh about 60 or 80 pounds. When the manufacture of salt is suspended by the coldness of the weather, the bittern is evaporated; during which, some common salt is separated and reserved for the purpose of concentrating the brine in summer.

The evaporated brine is then removed into coolers, where, if the weather prove cold and clear, Epsom salt crystallizes; the quantity of which is about one-eighth of the boiled liquor, and four or five tons of it are obtained from a quantity of brine, which has yielded 100 tons of common salt, and one ton of cat salt. This single Epsom salt being again dissolved and crystallized, is called double Epsom salt. As Bergmann had erroneously excluded sulphate of magnesia from the composition of sea water, his authority has led some to suppose that either sulphuric acid or some sulphate must be added to the bittern to manufacture Epsom salt, which is not the case.

In Cheshire, the water of the river Mersey is saturated with rock-salt, so that 100 tons of the brine will yield at least 23 tons of common salt; whereas, the same quantity of sea-water,

with an equal expenditure of fuel, would produce only 2 tons 17 cwt. of salt.

Some attempts have been made to use rock-salt, crushed between iron rollers, to the packing of provisions; but the results are not perfectly known.

A large proportion of what is sold in London as bay salt, is Cheshire large grained, or fishery salt.

1000 parts of St. Ube's bay salt contain 960 of muriate of soda, 4½ of sulphate of magnesia, 23½ of sulphate of lime, 3 of muriate of magnesia, a trace of muriate of lime, and 9 of insoluble matter.

St. Martin's bay salt contains 959½ muriate of soda, 6 sulphate of magnesia, 19 sulphate of lime, 3½ muriate of magnesia, a trace of muriate of lime, and 12 of insoluble matter.

Oleron bay salt contains 964¼ muriate of soda, 4¼ sulphate of magnesia, 19½ sulphate of lime, 2 muriate of magnesia, a trace of muriate of lime, and 10 of insoluble matter.

Scotch common salt contains 935½ muriate of soda, 17½ sulphate of magnesia, 15 sulphate of lime, 28 muriate of magnesia, and 4 of insoluble matter. The quantity of muriate of magnesia was however very variable.

Scotch Sunday salt contains 971 muriate of soda, 4½ sulphate of magnesia, 12 sulphate of lime, 11½ muriate of magnesia, and 1 of insoluble matter.

Lymington common salt contains 937 muriate of soda, 35 sulphate of magnesia, 15 sulphate of lime, 11 muriate of magnesia, and 2 of insoluble matter. Here also the quantity of muriate of magnesia is variable.

Lymington cat salt contains 988 muriate of soda, 5 sulphate of magnesia, 1 sulphate of lime, 5 muriate of magnesia, and 1 of insoluble matter.

Cheshire crushed rock-salt contains 983¼ muriate of soda, 6½ sulphate of lime, 3-16ths muriate of magnesia, 1-16th muriate of lime, and 10 of insoluble matter.

Cheshire fishery salt contains 986¾ muriate of soda, 11¼ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

Cheshire common salt contains 983¼ muriate of soda, 14¼ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

Cheshire stoved salt contains 982½ muriate of soda, 15¼ sulphate of lime, ¾ muriate of magnesia, ¼ muriate of lime, and 1 of insoluble matter.

The insoluble matter in foreign salt is chiefly argillaceous earth coloured by oxide of iron; in sea salt prepared by rapid evaporation, it is a mixture of carbonate of lime with carbonate of magnesia, and a fine silicious sand; in that from Che-

shire brine it is almost entirely carbonate of lime; in the less pure species of rock salt it is chiefly a marly earth with some sulphate of lime, and its quantity varies from 10 to 45 parts in a thousand; hence government allows 65 pounds for the legal weight of a bushel of rock salt, instead of 56 pounds, as in bay and white salt.

The earthy muriates seem to be derived from the mother liquor that adheres to the salt. They scarcely form one-thousandth part of the Cheshire varieties of salt; and indeed if the brine be evaporated to dryness, it does not contain more than 5 parts in 1000 of earthy muriates, whereas the entire salt of sea water contains 213.

That sulphate of lime is found in a larger proportion in bay salt than even in those that are prepared by the rapid evaporation of sea water, seems owing to its being either separated from the latter brines in the clearing of the boiler, a process which cannot be performed in the clay-pits, or to its entering into the composition of the pan scale. The proportion of it is very variable, depending upon the period in which the salt was extracted from the boiler; for common salt taken out two hours after the first application of heat, contained 16 parts in a thousand of sulphate of lime; four hours, 11 parts; and six hours, only 3½ parts. On the other hand, the contamination of salt with the earthy muriates increases as the process advances.

The several varieties of salt appear to contain nearly the same quantity of water after they have been dried by a heat of 212° Fahrenheit. Pure transparent rock-salt did not lose any of its weight in a low red heat, nor did it decrepitate, like the artificial varieties, when suddenly and strongly heated. The salts that contain muriate of magnesia are decomposed and deprived of their acid, by a low red heat. 100 parts of dry large grained fishery salt loses about three parts of water, St. Martin's bay salt, the same; Oleron bay salt 2½; Cheshire common salt, 1½; Cheshire stoved salt ½. The loudness of the decrepitation was in the same order, and was most remarkable in the large grained varieties.

The proportion of the other ingredients in the muriate of soda contained in these salts appeared to be nearly the same in all, and the difference existing between them for economical purposes, do not depend upon any difference in their chemical composition, but on the magnitude of their crystals, and their degree of compactness and hardness. Quickness of solution is, in similar circumstances, proportional to the quantity of surface exposed, and therefore since the surfaces of cubes are as the squares of their sides, a salt whose cubic crystals are of a given magnitude, will dissolve four times more slowly than one whose cubes have only half that size: of course the large

salt will, when used for packing provisions, remain permanently between the layers, or will be very gradually dissolved by the exuding fluid; on the other hand, the smaller grained salts answer equally well, if not better, for the purpose of preparing the pickle, or striking the meat.

Little or no difference in specific gravity is discoverable between the large grained salt of British, and that of foreign manufacture; and even if no superiority be claimed on account of the greater chemical purity of British salt, it may safely be asserted that the larger grained varieties are fully equal to foreign bay salt, as to their mechanical properties, and that the prejudice in favour of the latter may be discarded as imaginary.

Tincal, or Rough Borax.

Tincal, or rough borax, is imported from the East Indies, where it is said to be obtained by evaporating the water of certain lakes, either in shallow basins, as in making bay salt, or by fire: the tincal thus obtained, is then moistened with sour milk, in order to prevent the crystals from falling to powder.

1000 parts of tincal were found, by Klaproth, to contain 145 of soda, 370 of boracic acid, and 470 of water: that is to say, $Na.B^{8} + 24\,(H{\cdot}H_{2})$ according to Berzelius' notation.

Tincal is used for manufacturing refined borax.

Refined Borax.

The refining of tincal into borax was formerly considered as a great secret; and its manufacture was confined to Holland: as the numerous attempts of the chemists of other nations were unsuccessful, apparently from their ignorance that an addition of soda was requisite to saturate the surplus boracic acid in tincal.

Refined borax may be obtained by calcining tincal, boiling it with the necessary quantity of carbonate of soda, filtering the solution, and letting it cool: the small crystals thus obtained, are to be again dissolved in water, and crystallized as before, only letting the solution cool very gradually, as in crystallizing sugar.

Another method is, to put the tincal upon a cloth stretched over a colander, so as to form a layer of not more than a foot thick; it is then washed with a small quantity of pure soda water at 5 degrees Baumé, until the soda water passes but slightly coloured. The washed tincal is thrown gradually into a leaden boiler of water, until the water acquires the strength of 20 degrees Baumé; twelve pounds of carbonate of soda are then added for every 100 of washed tincal in the water; the ley is then left to settle and crystallize.

The mother waters being very highly coloured, are evaporated to dryness, then calcined, again dissolved, and the solution crystallized as before.

But at present, the French have ceased to import tincal, and manufacture all their borax, of which they annually consume about twenty-five tons, from the boracic acid obtained from the Italian lakes.

For this purpose, the manufacturer dissolves, gradually, 1200 pounds of carbonate of soda in 1000 pounds of water, and adds, by twenty pounds at a time, 600 pounds of Tuscan boracic acid. As the effervescence is considerable, the leaden boiler must hold double the quantity, and a fresh parcel of acid must not be added until the surface of the water is cleared.

The whole of the acid being added, the fire is stifled by a covering of ashes placed over the coals; the damper in the chimney is shut to prevent any draught; the boiler is covered with a double lid made of sheet lead, and blankets thrown over that to keep in the heat. At the end of thirty hours the cleared liquor is drawn off into leaden coolers, where its depth should not exceed a foot, where the first crop of crystals will be formed in three or four days.

As the market requires the crystals to be of considerable size, the first crop is struck off the coolers by a chisel and mallet, and re-dissolved in boiling water, adding one-tenth of their weight of carbonate of soda, until the ley is at 20 degrees Baumé; and, to attain the proper marketable size, as Dutch refined borax, not less than a ton of borax should be crystallized at once. The solution being finished, it is drawn off into a large square wooden cistern, about six feet each way, lined with very thick sheet lead, several of which ought to be prepared, and fixed in another case at such distance as to allow the cistern, containing the liquor, to be surrounded on all sides, and also covered at top with woollen mattresses to keep in the heat. Here the solution must remain at perfect rest for seventeen or eighteen days before it cools to 86 degrees Fahrenheit. When the cistern is opened, the mother water is drawn off by a syphon, and the cistern shut up again for six or eight hours to cool slowly, that the crystals may not crack.

At the last, the crystals are adroitly cut out of the cistern with a sharp chisel, in large masses, and afterwards broken into separate crystals; those that are less weight than two avoirdupois drams are flung aside, and if the larger crystals have any spots of borate of lime, or borate of magnesia attached to them, these spots are struck off by a sugar hatchet.

The small crystals are added to the next batch; and the mother water of the first crop of crystals is used to dissolve the carbonate of soda for the succeeding batches.

One hundred pounds of the best Tuscan boracic acid, containing about half its weight of the pure acid, produces in experiments about 150 of refined borax; but, as the ordinary acid

contains only about 48 pounds of pure acid, and there is a considerable loss in the repeated solutions necessary to obtain full-sized marketable crystals, the manufacturer cannot expect more than 140 or 142 pounds of borax from 100 of boracic acid.

The manufactories must be placed where the crystallizing cisterns are not exposed to the vibration occasioned by carriages passing along paved streets; and these must be so solidly fixed, that the knocking of the crystals from one cistern may not communicate any motion to the others, as this would prevent the crystals from obtaining their full size.

In consequence of this improvement, the price of refined borax has fallen in France from about five shillings and ten-pence the pound to two shillings and two-pence; and it might be sold lower if the consumption was increased.

Borax is used in soldering; in forming artificial gems; in melting the precious metals; and in glazing china-ware.

Refined borax, the *bi-borate of soda* of Thomson, contains 2 B: $Na + 8 H$, equal to 19,000; but Berzelius makes his *boras natricus* N: $B^2 + 10 (H H_2)$ or 2,453,820.

Rochelle Salt.

This purgative salt, used by the higher classes in society, is the *tartarate of potassa and soda;* or, rather, the *potassa tartarate of soda* of the chemists, and the *soda tartarizata* of the medical faculty.

It is formed by dissolving twenty ounces of carbonate of soda in ten wine pints of water, and adding, gradually, twenty ounces of cream of tartar, filtering the solution, evaporating it to a skin, and crystallization.

According to Berzelius, his *tartras kalico natricus cum aqua* is probably K: $T^2 + N$: $T^2 + 20 (H H)$ equal to 7,548,390: Thomson makes it $K T + N T 8 H$, or 35,500; and Phillips agrees with Thomson, as to the composition of the salt, but says it contains no water of crystallization; so that he makes it 214, supposing hydrogen to be the unity, or 26,750 on Thomson's scale.

Phosphate of Soda.

This was originally known by the name of *sal mirabile perlatum;* but was introduced into more general notice by that of *tasteless purging salt.* It is used in chemistry to discover magnesia in mineral waters and acid solutions.

It is made by dissolving 1400 grains of crystallized carbonate of soda in 2100 of water, at 150 degrees Fahrenheit; to this is to be added, gradually, 500 grains of phosphoric acid, specific gravity 1·85, boiling the mixture for a few minutes, filtering it, and letting it crystallize by cooling; from 1450 to 1550 grains of phosphate of soda crystallizes.

Or, forty wine pints of boiling water are poured on twenty pounds of bone ash, and sixteen pounds and a half of oil of vitriol, previously diluted with an equal weight of water, added; the next day the liquor is strained off, and the sediment washed,

to get out all the acid; the whole of the mixed liquors is evaporated to half its quantity, left to settle, and then strained, evaporated again to dryness, melted in a crucible, and dissolved in water. Carbonate of soda is added to the impure phosphoric acid thus obtained, to throw down the remains of the lime, and the liquor is then filtered and crystallized.

Microcosmic Salt.

This salt, which is much used in assaying minerals by the blow-pipe, was originally extracted from urine, and hence derived its name of *fusible salt of urine;* it is also called *salt of phosphorus*, as in Berzelius' Treatise on the Blow-pipe; but the theorists denominate it *phosphate of ammonia and soda*, or *ammonia phosphate of soda.*

Berzelius makes it by dissolving sixteen parts of sal ammoniac in a very small quantity of boiling water, adding 100 parts of crystallized phosphate of soda, filtering the solution, and letting it cool slowly, when small crystals are formed. The mother water contains common salt and an acidulous phosphate, which will require to be saturated with ammonia, if it be desired to make use of this water. If the microcosmic salt is not pure, it melts into an opake globule, and must be re-dissolved and re-crystallized.

Succinate of Soda Water.

This is only used as a means for discovering iron in mineral waters and acid solutions, and separating that metal from them.

It is prepared by adding succinic acid to carbonate of soda water, so that the liquor may contain a slight excess of acid beyond what is necessary for the saturation of the soda.

VOLATILE ALKALI, OR AMMONIA.

This alkali has escaped very well in the mania for changing names, although some theorists are for giving it a name that may denote its supposed composition from azote or nitrogen gas, and hydrogen gas; since, according to the theory of the common schools, it is formed from three measures of hydrogen gas, united with one of azote or nitrogen gas, condensed into two measures, or half the bulk of its constituent elements; and hence its atomic weight, according to Thomson, is 2,125. Berzelius, on the other hand, makes it $N{\cdot}H^6$, and its weight 214,570; so that, according to this theory, 100 parts of it contain 46 parts ·6 of oxygen: and, indeed, its power of saturating acids is equivalent to that of other alkaline bases containing that proportion of oxygen.

Pure ammonia, ammoniacal gas, or, as it was originally called by its discoverer, Dr. Priestley, *alkaline air*, is obtainable from ammonia water by a gentle heat. It must be collected in jars standing in a trough of quicksilver, as it is rapidly absorbed by water, one measure of which takes up 780 measures of the gas. It is of no use.

Ammonia Water.

This was originally called *spirit of sal ammoniac made with lime*, then *volatile alkaline spirit of sal ammoniac*. It is the *liquor ammoniæ* of the present medical faculty; and the *liquid ammonia* of many chemists, though this name now denotes the condensed gas.

It may be prepared, in a small way, by slaking six ounces of quicklime with a pint of water, and, in an hour's time, adding a boiling hot solution of eight ounces of sal ammoniac in three pints of water, covering the vessel, straining the liquor when cold, and distilling off twelve ounce-measures into a receiver, kept in a tub of water at 50° Fahr.

Mr. Woulfe made the following experiment on the distillation of sal ammoniac with quicklime. Twelve pounds of British sal ammoniac, and twenty-six pounds of quicklime, were powdered, mixed, and put into an iron body, with a stone-ware head, to which his first apparatus was fitted; and, when the apparatus was luted, a gallon of water was poured on it through the pipe in the top of the head, which was immediately stopped. The lime growing hot produced a vast quantity of elastic air, which, though highly charged with volatile alkali, was condensed by the water, only the air escaping at the top of the vessel, with hardly any sensible volatile alkaline smell. Next morning, all being cold, another gallon of water was added as before, and a very slow fire made under the body for fourteen hours, in which time there distilled nearly a pound of volatile alkali; the fire was then made stronger, and continued in that state for twelve hours more; in which time there was obtained, together with what was first distilled, eight pounds and a quarter of volatile alkali, strong, and fit for eau de luce; this was taken out of the bottle and set apart. The vessels being cool, two gallons more of water were put into the body, and the fire made as before, and continued till there were seven pounds distilled of weak volatile spirit: this spirit answers better than water in case of a fresh distillation.

During the first sixteen hours of the distillation, there continually escaped through the water in the bottle air very slightly charged with volatile alkali, especially when the water got hot; but afterwards no air was set free.

Two stone gallon bottles, with three quarts of water in each, were made use of to condense the vapours; and when one bottle was got warm by the fumes, the other was put in its place, while it was cooling in a vessel of cold water, and so continually changed during the whole operation. The six quarts of water increased by this means two pounds and a half in weight; and, by the following experiments, it appears that a pound of this vapour condensed in the water, is to a pound of the volatile alkali, which was set apart for eau de luce, as 140 to 76, which is nearly

twice as much; therefore there was a saving of nearly five pounds of volatile alkali, which would have been lost in the common manner of distillation.

The water of the two stone bottles, charged with alkaline vapours, was mixed, in order to reduce them to the same degree of strength, and as much of it was put into a glass body as contained four ounces of the alkaline vapour; four ounces of the volatile alkali, which was set apart for eau de luce, was put into another body of the same size, and diluted with water to the same bulk of the other.

This last took one pound three ounces of oil of vitriol, diluted with water, to be saturated, and did not become hot; whereas, the water, containing the four ounces of the alkaline vapour, absorbed by water, required two pounds three ounces of the same acid, and got so very hot, that the vessel could scarcely be held in the hand, even after having been diluted, at different times, with two quarts of water. This shows that there is a great difference in the two, and that it is not entirely owing to strength. The heat produced by the vapours passing through the water was tried at another distillation, and the heat was raised to 110 degrees Fahrenheit.

In rectifying caustic volatile alkali with lime, there is likewise a very great quantity of air set free, highly charged with volatile alkali, which condenses in water and heats it. Water may be so strongly charged with this vapour, that it will make very strong eau de luce, nay, much stronger than that which was distilled and set apart for eau de luce; but it is necessary to make use of two stone bottles, changing them as often as they get warm.

The specific gravity of ammonia water, for medical purposes, is ordered to be 0·960, and contains about one-tenth its weight of ammoniacal gas; but Dr. Henry advises that used for the examination of mineral waters and acid solutions to be kept at 0·970, in order that a measure of it may saturate an equal measure of sulphuric acid at 1·135, of nitric acid at 1·143, of muriatic acid at 1·074. The strongest ammonia water that can be kept, without extraordinary care, is at 0·954, which contains very nearly one-third its weight of ammoniacal gas, or 15 atoms of water to one of ammonia.

Sulphate of Ammonia.

This is now made from the ammoniacal liquor obtained as a secondary product in the distillation of coal for gas. A chaldron of Newcastle coal yields, in general, about 200 pounds of ammoniacal liquor, which chiefly consists of sulphate of ammonia and carbonate of ammonia. A gallon, or eight pounds and a half of that obtained from strong burning coal, usually requires for its saturation from fifteen to sixteen ounces of oil of vitriol, of the specific gravity 1·840; but the same quantity of liquor from coals burning to a white ash, do not require more than nine ounces.

The strength of the liquor must be first ascertained, by putting several half pints of it into different vessels, and adding to each a different number of avoirdupois drams of calcined gyp-

sum, reduced to fine powder: the mixture is well stirred and left for three or four hours. Pieces of paper, tinged blue with archil, are then dipped in each vessel, and that vessel is noted in which the archil paper is turned red with the smallest quantity of calcined gypsum.

The ammoniacal liquor being measured, or gauged, to every eight gallons there is to be added calcined gypsum, in the proportion of a pound for every dram that the assayed half pint required. The mixture is stirred together, and when it has settled, the liquor is drawn off and evaporated; at first a portion of sulphate of lime falls down, and must be removed; the sulphate of ammonia then begins to show its crystals, which are drawn out of the boiling liquor, and drained in baskets placed round the boiler, so that the liquor that drains off may run into the boiler again, and this is continued until the whole is evaporated to dryness.

Eighty-four pounds of sulphate of ammonia are, upon an average, produced from 54 gallons of the ammoniacal liquor from Newcastle coals, and 63 pounds of calcined gypsum.

Sometimes the ammoniacal liquor is saturated with oil of vitriol; but in this case, the sulphate of ammonia is contaminated with oil, which must be got rid of, by heating it gently, with constant stirring that every part may be heated alike, until one part of the oil being steamed away, and the other reduced to a coal, the solution in water is colourless.

Sulphate of ammonia is used for the manufacture of sal ammoniac and volatile salt. It contains one atom each, acid, alkali, and water; but that analysed by Berzelius contained two of water.

Nitrate of Ammonia.

This has been called *nitrum flammans*, from its sudden expansion by heat. It has but lately come into use for the production of nitrous oxide gas, or intoxicating gas.

It is made by saturating dilute nitric acid with sesqui carbonate of ammonia, evaporating the liquid, if necessary, and letting it crystallize.

This salt consists of one atom each of ammonia and of nitric acid; and according to Sir H. Davy, it varies in its proportion of water, assuming a correspondent variety of form.

Sal Ammoniac.

The name bore by this salt for nearly 2000 years, has been lately changed by the southern chemists into that of *muriate of ammonia*, and by the northern chemists into *murias ammonicus*.

It has been in common use for several centuries, and was formerly brought from Egypt. Nothing was for a long time known of the constituents of the salt, or of the mode of preparing it. In the year 1719, the French consul at Grand Cairo, M. Lemeri, sent an account of the mode of manufacturing it in Egypt. The

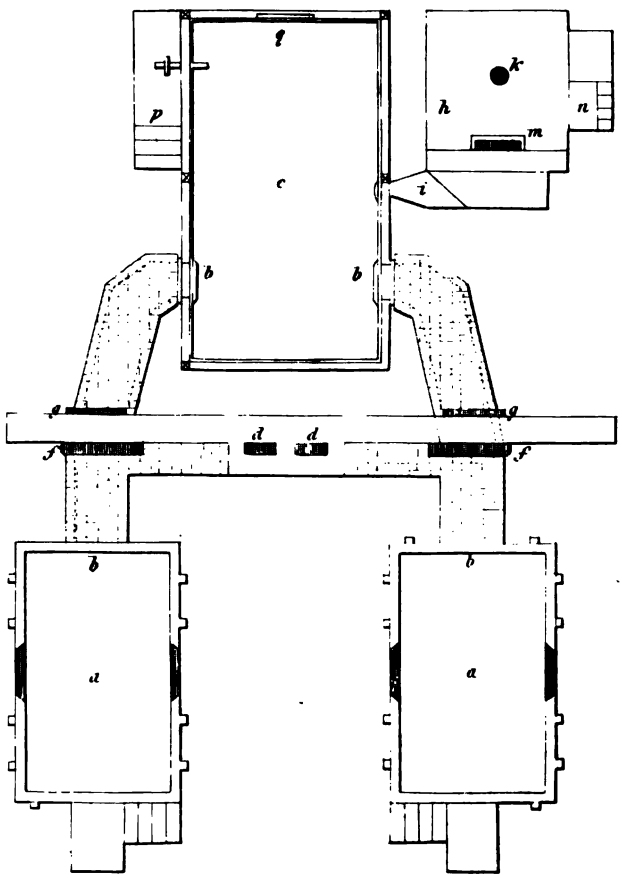
natives collect the excrements of camels, oxen, and other animals, which feed on saline plants. This is dried and used as fuel, the soot is collected and put into large glass bottles, 18 or 19 inches in diameter, terminating in a neck several inches high. The bottles are filled within four fingers' breadth of the top, and then heated for three days. Towards the second day sal ammoniac sublimes and adheres to the upper part of the bottle. When the process is finished, and the vessels cooled, they are broken, and the sal ammoniac taken out for sale. About one pound of sal ammoniac is obtained from five pounds of soot.

After the discovery of its constituent parts, establishments for manufacturing it were soon set on foot in various parts of Europe. The first were in England and Scotland; it was known that carbonate of ammonia is disengaged from several animal substances in the process of putrefaction, and could be obtained in great abundance by subjecting the horns, bones, and hoofs of animals, or fish, to distillation; the most obvious method of effecting the combination, was a direct mixture of the acid and alkali, but owing to the waste of the gaseous alkali, this mode was soon found not to be economical.

Fig. 113, represents the ground plan of an apparatus employed by M. Leblanc, at St. Denis, near Paris, for manufacturing sal ammoniac, by decomposing common salt by sulphuric acid, in a kind of reverberatory furnace, the floor of which is covered with lead, and the vapour of muriatic acid being conveyed into an adjoining leaden chamber, it is there at the same instant met by the vapour of carbonate of ammonia, produced from animal matters, which are distilled in three iron cylindrical retorts placed in a furnace. The decomposition of the common salt is not, however, entirely effected in a first furnace, so that it is removed into a second, capable of giving a great heat. The alkaline residuum of the salt is employed to furnish crystallized soda.

A, are two furnaces for decomposing common salt, each 14 feet long, by seven feet six inches wide. *B*, are brick gutters, each two feet wide, which go through the wall dividing the workshop, and conduct the vapours of muriatic acid gas into the chamber, *c*, which is made of lead, and here the muriatic acid meets the ammoniacal gas for the production of sal ammoniac. *D*, are flues belonging to the two furnaces, *a*, for carrying off the smoke of the fire places. These are 14 inches by 24 inches each, and are carried up together, and at last united into one chimney above the top of the building. *E*, are pipes belonging to the two furnaces, *a*, each 14 inches wide, connected with the chimneys, and designed for carrying off the muriatic acid gas by that conveyance into the atmosphere, when the furnaces are used for the production of soda without making sal ammoniac. *F*, are cast iron plates, or dampers, which open or shut the communication of the pipes, *e*, with the chimney, at pleasure. *G*, are similar iron dampers, which cut off the passage of the muriatic acid gas into the leaden chamber. *H*, is a ground plan of the kiln for burning the animal matters designed to produce ammonia. *I*, a leaden pipe to convey the ammoniacal gas into the chamber, *c*. *K*, is a hole through the arch, or superior part of the kiln, which is designed to receive a retort, from whence the steam of hot water is forced into the chamber, *c*, at the same moment when the acid and alkaline gasses are entering the same receptacle. *M*, the kiln chimney. *N*, is a flight of steps leading to the ash room. *O*, a pipe by which the chamber is emptied of the liquid muriate of ammonia, when necessary. *P*, a flight of steps leading under the chamber, *c*. *Q*, a door to enter the said chamber. The peculiar advantage of this apparatus is, that while the muriatic acid gas is passing to the chamber, *c*, at that moment another stream of ammoniacal gas is enter-

Fig. 113.



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ing the same chamber from the kiln, *h*, which occasions a mutual condensation, and prevents any loss.

This salt is also manufactured from carbonate of ammonia, acted upon by sulphate of lime. Rough bone spirit is digested on ground plaster of Paris, which, in consequence of a double decomposition, is changed into carbonate of lime, and the liquor contains sulphate of ammonia.

Common salt is then added in the requisite proportions to the solution of sulphate of ammonia in water, and the liquor is evaporated; the Glauber's salt formed crystallizes, and is separated, until the muriate of ammonia begins to show itself in feathered stars, and then the liquid is run off into coolers, where the sal ammoniac crystallizes. When the liquid is cooled to 76° Fahr. the mother water must be again drawn off for a fresh evaporation, as below that temperature Glauber's salt would be deposited, and mix with the sal ammoniac.

The moist sal ammoniac is drained, and then sublimed in earthen jars, or glass bolt-heads.

The use of coal gas lights having introduced a quantity of ammoniacal liquor into the market, the sulphate of ammonia made from it has been used for the manufacture of sal ammoniac.

Sal ammoniac is used by dyers to modify the shades of various colours, and it is added in considerable quantity to snuff, to make it pungent. A large quantity is used by the workers in metals, particularly in soldering; it is said that twenty tons are used yearly in Birmingham, by these artificers.

Sal ammoniac, newly sublimed, or well dryed, consists, according to Berzelius, of $N \cdot H^6 M$:, equal to 558,090, but according to Thomson, of $Cl\,H + Az\,H^3$, equal to 6,750.

Hartshorne, or Bone Spirit.

This is also called *crude ammonia*, and the manufactory of it is carried on upon a large scale in several parts of the kingdom. The materials distilled are in general bones and hoofs of animals: though the refuse of slaughter-houses, and urine, is used for the same purpose.

In this distillation an iron still or retort is generally used, with a pipe leading from it, connected with a worm-tub. The vessel being filled with bones roughly broken, or other material, a strong heat is applied. Water, and a tar-like oil, first comes over, accompanied by a very fetid inflammable gas. Carbonic acid gas also comes over, but the latter is mostly taken up by the ammonia, which is also formed at the same time, and they come over into the receiver in the state of carbonate of ammonia. When the different substances have been condensed in the worm, they should pass into a receiver, which has no communication with the open air, as this would

not only render it almost impossible to exist in the same place, but would constitute a nuisance in the vicinity of any town.

The receiver should have no opening outwards, but through a pipe inserted into the upper part of it, and connected with the ash room of the still. The inflammable gas and the smell are conveyed to the fire, where the former takes fire and burns; but care must be taken to avoid any explosion, for when the evolution of the inflammable gas becomes slow, or ceases entirely, the common air passes along the pipe into the close receiver, which is filled with the same inflammable gas; and under these circumstances an explosion will take place, which will not only burst the receiver, but do other injury. This evil may be avoided by placing a valve in the pipe, opening outwards, to allow the passage of the gas, and another valve in the receiver, opening inwards, by this means the flaming gas will be stopped in its passage to the receiver; as the valve into the receiver opening will admit the common air to fill up the vacuum. And thus by means of this apparatus, if it be well constructed, and proper luting employed, the distillation of hartshorn may be carried on almost without any smell, although the odour of animal oil is so remarkably offensive.

The first product consists of water, animal tar, and volatile salt. A great part of the tarry oil may be separated mechanically; the rest, in great measure, by a second distillation with a gentle heat. The liquid which comes over consists of a solution of sesqui carbonate of ammonia, with a fetid animal oil, which gives it a peculiar odour. This liquid has been sold in the shops under the name of *spirit of hartshorn*, as the alkaline liquor obtained from that substance, was at one time thought to possess certain medical virtues, not to be found in the alkaline liquor obtained from other animal matters.

Hartshorn, or bone spirit, is used for preparing sulphate of ammonia, and for purposes in which the smell of the oil is not of any consequence.

Volatile Salt.

The original name of this salt, was *volatile salt of sal ammoniac*, or the *volatile salt* of the substances from which it was procured, being mostly hart's horn, vipers, or urine. In the French nomenclature it was *carbonate of ammonia;* this has been changed by some into *sub-carbonate of ammonia*, but lately it has been called the *sesqui carbonate of ammonia*, as the freshest specimens always contain a charge and a half of carbonic acid, to one of ammonia, and its alkali gradually flies off from the exterior surface, which is thus converted into the bi-carbonate of ammonia, the interior generally remaining unchanged.

It is obtained in the distillation of most animal substances, and of some few vegetables; but when prepared in this manner it is contaminated with an oil, which, except in the case of being obtained from the cast horns of deer is very unpleasant.

Volatile salt is sometimes made, by subliming a mixture of eight ounces of sal ammoniac, with ten ounces of chalk, both previously well dried.

At present it is mostly prepared from purified sulphate of ammonia, which is mixed with one quarter of its weight of chalk, finely ground and previously deprived of its moisture by heat. As soon as possible after the mixture is made, it is introduced into cast-iron retorts, at a dull red heat, but as soon as the lids are made air-tight, the fire is raised gradually, till the retort becomes a bright cherry red. The carbonate of ammonia is conveyed by a four-inch pipe, which proceeds from the upper extremity of each retort, opposite to the mouth-piece, into a barrel-shaped leaden, or cast-iron receiver, where it condenses. The receiver is furnished with a leaden cover, secured by a water joint; it is provided also at its bottom with a small pipe, furnished with a stopper, and till the liquid products are got rid of during the process of sublimation, this pipe is left open. To give vent to the elastic fluid, evolved during the process, a small hole is made in some convenient part of the cover, which is slightly stopped by a wooden peg. The receiver should be supported upon a stand, so as to raise it a foot or eighteen inches from the ground.

The time which is necessary for completing the operation, varies according to circumstances, but the sublimation of a charge of 120 pounds of the mixture in one retort, is usually finished in twenty-four hours.

Dry sulphate of ammonia produces about half its weight of sesqui carbonate of ammonia.

Volatile salt is used as a stimulating odorous substance, either pure in smelling bottles, or mixed with snuff. It is also used in large quantities by the bakers, to raise their bread lighter and quicker than by yeast alone.

Bi-Carbonate of Ammonia Water,

Is prepared by merely exposing sesqui carbonate of ammonia in small grains to the air, until it has lost its pungent smell, and then dissolving it in water.

It is used to ascertain the presence of magnesia in mineral waters, or acid solutions.

Oxalate of Ammonia Water,

Is prepared by saturating liquid oxalic acid with volatile salt.

It is used to ascertain the presence of lime in mineral waters.

Benzoate of Ammonia Water,

Is prepared by saturating liquid benzoic acid with volatile salt.

It is used to ascertain the presence of iron in mineral waters, and acid solutions.

LIME.

Lime is considered as the oxide of a metal called calcium. Berzelius makes it Ca:, and its weight 712,060; and Dr. Thomson only C·, or 3,500. It is generally considered as an earth, but is soluble in 700 times its weight of water, and the water has an acrid taste, and turns syrup of violets green.

Quicklime.

Quicklime is obtained from limestones, chalk, or shells, by burning them in kilns.

Lime kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel which are to be employed.

The best form of a lime kiln, in the practice of the present day, is that of the egg placed upon its narrower end, having part of its broader end struck off, and its sides somewhat compressed, especially towards the lower extremity: the ground-plat, or bottom of the kiln, being nearly an oval, with an eye or draft-hole towards each end of it. It is supposed that two advantages are gained by this form over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off so freely as it does in that of a spreading cone: on the contrary, it thereby receives a degree of reverberation which adds to its intensity. But the other, and still more valuable effect, is this: when the cooled lime is drawn out at the bottom of the furnace, the ignited mass, in the upper parts of it, settles down, freely and evenly, into the central parts of the kiln.

It is a common practice, in some places, to burn limestone with furze or fagots. The kilns which are made use of in these cases are commonly known by the denomination of flame-kilns, and are built of brick; the walls from four to five feet thick, when they are not supported by a bank or mound of earth. The inside is nearly square, being twelve feet by thirteen, and eleven or twelve feet high. In the front wall there are three arches, each about one foot ten inches wide, by three feet nine inches in height. When the kiln is to be filled, three arches are to be formed of the largest pieces of lime-stone, the whole breadth of the kiln, and opposite to the arches in the front wall. When these arches are formed, the lime-stone is thrown promiscuously into the kiln to the height of seven or eight feet, over which are frequently laid fifteen or twenty thousand bricks, which are burned at the same time with the lime-stone. As soon as the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost

to the top, room being left in each sufficient only for putting in the furze, which is done in small quantities, the object being to keep a constant and regular flame. In the space of thirty-six or forty hours, the whole lime-stone, about one hundred and twenty, or one hundred and thirty quarters, together with the fifteen or twenty thousand bricks, are thoroughly burnt.

Mr. Dodson is convinced, from experience, that lime-stone can be burnt to better purpose, and at less expense, with peat than with coal. When coal is used, the lime-stones are apt, from excessive heat, to run into a solid lump, which never happens with peat, as it keeps them in an open state, and admits the air freely. The process of burning, also, goes on more slowly with coal. No lime can be drawn for two or three days; whereas, with peat, it may be drawn within twelve hours after fire is put to the kiln; and, on every succeeding day, nearly double the quantity of what could be produced by the use of coal. The expense is comparatively small. No particular form of kiln was found necessary, nor any particular sort of management in the process of calcination.

Mr. Rawson asserts that he has produced a considerable saving in the burning of lime, by closing his kiln at top, and building a chimney over it. His kiln is twenty feet in height, at the bottom a metal plate is placed, one foot in height, intended to give air to the fire. Over this plate the shovel that draws the lime runs. The sloped sides are six feet in height, the breadth at the top of the slope is eight feet, the sides are carried up perpendicular fourteen feet, so as that every part of the inside, for fourteen feet, to the mouth, is exactly of the same dimensions. On the mouth of the kiln a cap is placed, built of long stones, and expeditiously contracted, about seven or eight feet high. In the building of the cap, in one side of the slope, the mason is over the centre of the kiln, so that any thing dropping down will fall perpendicularly to the eye beneath. He is here to place an iron door of eighteen inches square, and the remainder of the building of the cap is to be carried up, until the hole at the top be contracted to fourteen inches. The kiln is to be fed through the iron door, and, when filled, the door close shut. The outside wall must be three feet at the bottom to batten up to two feet at top, and made at such a distance, from the inside wall of the kiln, that two feet of yellow clay may be well packed in between the walls, as every kiln, built without this precaution, will certainly split, and the strength of the fire be thereby exhausted. At eight feet high from the eye of the kiln, two flues should be carried through the front wall, through the packed clay, and to the opposite side of the kiln, to give power to the fire.

As many situations will not admit of building a kiln twenty

feet high, while other situations may allow of its being thirty, or even forty feet (for it cannot be made too high,) the diameter of the kiln should be proportioned to the height to which it is carried up.

Fig. 114, represents an elevation of the usual form in which kilns to burn lime with coal are frequently built. *A*, is the front wall of the kiln; *b*, part of a slope made to enable the workmen to mount up to the top of the kiln, to charge it with coal and lime-stone, in alternate beds. *C*, one of the three arches that lead to the fire-room, and through which the lime is withdrawn.

Fig. 115, represents the section of the kiln. *A*, the solid mass of the kiln; *b*, linings of brick or stone; *c*, the hollow cavity of the fire-room and chamber; *d*, mouth of the fire-room and ash-room; *e*, two of the three arches that lead to the fire-room entrance.

Fig. 116, represents the plan of the kiln. *E*, the three arches leading to the fire-room; *o*, iron bars placed across the bottom of the fire-room, to serve as a grate and supporter of the lime-stone.

Fig. 117, represents a section of a kiln for burning lime, by means of furze or wood. *A*, the main mass of the kiln; *b*, the brick lining of the cavity where the fire and lime-stone are placed; *c*, the chamber fitted with lime-stone; *d*, the fire-room; *e*, a workman, who is putting a fagot to the mouth of the fire-room, and holds it there until it is perfectly alight, when he drops it into the fire-room, and immediately stops up the fire-room door with another fagot, and so keeps on: *f*, the ash-room, which is an arched vault that crosses the bottom of the kiln; it has a hole in its middle which corresponds with the fire-room, and lets the small coal pass into the ash-vault.

In Cambridgeshire, and many of the southern counties of England, lime is prepared from the calcination of chalk, or, as it is generally called at Cambridge, clunch. The kilns are inverted cones sunk in the earth, and lined with brick; the base of the cone is about ten feet in diameter, and the depth of the kiln is about fourteen feet. One of these kilns will burn about 150 bushels of lime in twenty-four hours; they use generally one bushel of coal for every four bushels of lime, and in summer, when the chalk is dry, they will sometimes get five bushels of lime from the consumption of one bushel of coals; but being dear, the chalk is seldom well burned.

In some parts of Yorkshire they burn pieces of calcareous slate, a foot in thickness, and a foot and half in length, without breaking them; they use generally eight dozen of coal to a kiln, and obtain 22 dozen of lime, the dozen containing 36 bushels.

On a medium of twelve experiments, 11 Cwt. 1 quarter, 4 pounds two-thirds of lime were obtained from a ton of calcareous stones, but the manufacturers do not calcine the stone so far; yet, notwithstanding the loss of weight, there is no decrease in bulk.

All kinds of lime exposed to the air, recover nearly their original weight, except chalk lime, which, although long exposed, never recovers more than seven-eighths of its original weight.

Fig. 114.

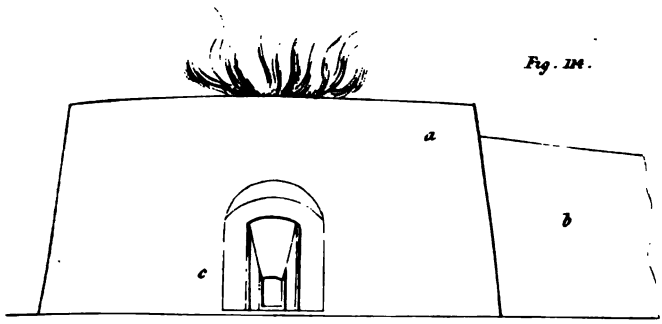
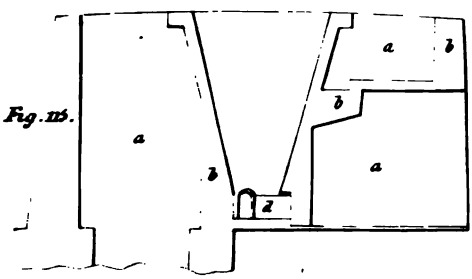


Fig. 115.



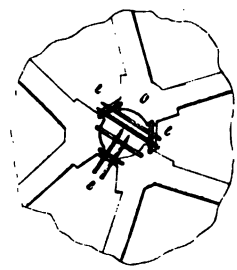


Fig. 116.

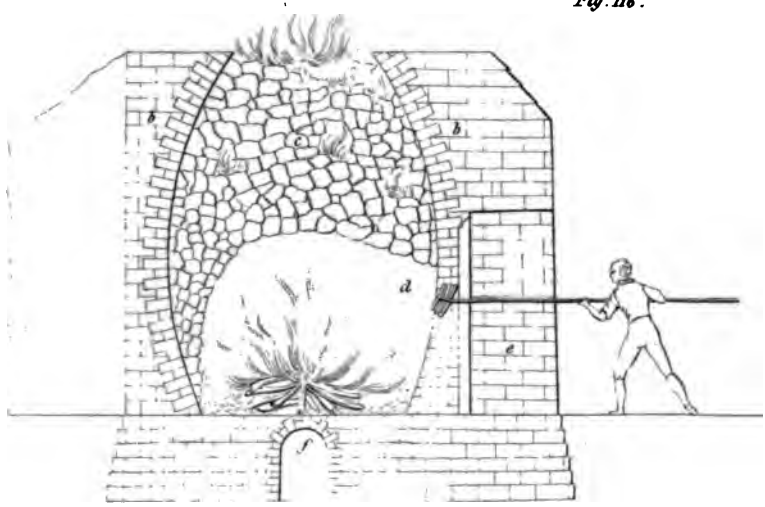


Fig. 117.

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ASTOR, LENOX AND
TILDEN FOUNDATIONS

Some lime-stones, as Portland stone, yield a very white lime, others, as chalk and roe stone, a lime with a yellowish cast; the latter is the best adapted for mixing with tarras, puzzolana, or Parker's cement, for buildings under water.

Lime is much used in agriculture as a manure, or rather a stimulant to vegetation; it is also used very largely in building.

Shell Lime.

The only lime they use in some places is made of shells, which are burnt to lime between the layers of a pile of wood, instead of a kiln, till it is reduced to ashes. The lime thus made, is reckoned very good; but as it is impregnated with the ashes of the wood, and the marine salt that is often in the shells, it is apt to make the houses that are built with it very damp in moist weather, so that the water often runs down their walls in streams, which cannot but be very unwholesome in an air that is naturally close and damp. The way to prevent which, would be, to wash and dry their shells frequently, and burn them with those kinds of wood that afford little or no alkaline salt.

Dead Lime.

It has long been observed by lime burners, that if lime stone be imperfectly burnt in the first instance, no farther exposure of it to fire will produce quicklime; but the contempt of the philosophical chemists for the observations of tradesmen has led them to doubt the truth of this observation. Mr. Vicat, however, in a work he has published upon mortar and stucco, has confirmed the observation of the lime burners.

He found that, in making quicklime in a small furnace, if the small pieces of lime-stone which fell through the grate into the ash-pit, before they were throroughly burnt, were collected and put again into the fire, even for several successive times, quicklime was not obtained, but a kind of lime technically called, dead lime, which will not slake with water, but which, on being ground and made into a paste with water, differs from common mortar by setting under water.

Staining Marble.

The staining marble is a nice art; and in order to succeed in it, the pieces of marble must be well polished, and clear from the least spot or vein. The harder the marble is, the better it will bear the heat necessary for the operation.

Heat is always necessary for the opening of the pores of the marble, so as to render it fit to receive the colours. The proper degree of heat is that which, without making the marble red, will make the liquor boil upon its surface. The solvents used to strike in its colours, must be varied according to the nature of the colour to be used. A mixture made with horse or dog's urine, with four parts quicklime, and one part potashes, is excellent for some colours; common ley of wood ashes, does very well for others; for some, spirit of wine is best; and finally, for others, oily liquors, or common white wine.

The colours which have been found to succeed best with the peculiar liquids, are these:—stone blue dissolved in six times

the quantity of spirit of wine, or of the mixture of urine and litmus, or archil, dissolved in common ley of wood ashes. An extract of saffron, and sap green, succeed well dissolved in urine and quicklime, and tolerably well in spirit of wine. Vermilion, and a fine powder of cochineal, succeed also very well in the same liquors. Dragon's blood succeeds very well in spirit of wine, as also does a tincture of logwood in the same spirit. Alkanet root gives a fine colour, but the only liquid to be used for this is oil of turpentine; for neither spirit of wine, nor any lixivium, will do with it. There is a kind called dragon's blood in tears, which, mixed with urine alone, gives a very elegant colour.

Besides these mixtures of colours and liquids, there are some colours which are to be laid on dry and unmixed. These are dragon's blood of the purest kind for a red, gamboge for a yellow, green wax for a green, common brimstone, pitch, and turpentine, for a brown colour. The marble for these experiments must be made considerably hot, and then the colours are to be rubbed on dry in the lump. Some of these colours, when once given, remain immutable; others are easily changed or destroyed. Thus the red colour, given by dragon's blood, or decoction of logwood, will be wholly taken away by oil of tartar, and the polish of the marble not hurt by it.

A fine gold colour is given in the following manner. Sal ammoniac, vitriol, and verdigris, are taken in equal quantities; white vitriol succeeds best, and all must be thoroughly mixed in fine powder.

The staining of marble to all degrees of red, or yellow, by solutions of dragon's blood, or gamboge, may be done by reducing these gums to powder, and grinding them with spirit of wine in a glass mortar. A pencil dipped in the tinctures, will make the finest traces on the marble while cold, which, on the heating of it afterwards, either on sand, or in a baker's oven, will all sink very deep, and remain perfectly distinct in the stone. It is very easy to make the ground colour of the marble red or yellow by this means, and leave white veins in it. This is to be done by covering the places where the whiteness is to remain with some white paint, or even with two or three doubles only of paper, either of which will prevent the colour from penetrating in that part. All the degrees of red are to be given to marble by means of dragon's blood alone; a slight tincture of it, without the assistance of heat to the marble, gives only a pale flesh colour. But the stronger tinctures give it yet deeper; to this the assistance of heat adds yet greatly; and finally, the addition of a little pitch to the tincture gives it a tendency to blackness, or any degree of deep red that is desired.

A blue colour may be given to marble by dissolving archil in

a lixivium of lime and urine, or in hartshorn or bone spirit; but this has always a tendency to purple, whether made by the one or the other of these ways. A better blue, and used in an easier manner, is furnished by the Canary archil. This needs only to be dissolved in water, and drawn on the place with a pencil; it penetrates very deep into the marble, and the colour may be increased by drawing the pencil wetted afresh, several times over the same lines. This colour is subject to spread and diffuse itself irregularly; but it may be kept in regular bounds, by circumscribing its lines with beds of wax, or any other such substance. It is to be observed that this colour should always be laid on cold, and no heat given, even afterwards, to the marble; and one great advantage of this colour is, that it is therefore easily added to marbles already stained with any other colours, and it is a very beautiful tinge, and lasts a long time.

This art in several people's hands has been a very lucrative secret, though there is scarcely any thing in it that has not at one time or other been published. Kircher, however, was one of the first who published any thing practicable about it. The author, meeting with stones in some cabinets, supposed to be natural, but having figures too nice and particular to be supposed to be nature's making, and these not only on the surface, but sunk through the whole body of the stones, was at the pains of finding out the artist who did the business; and, on his refusing to part with the secret on any terms, Kircher, assisted by Albert Gunter, a Saxon, endeavoured to find it out; in which they succeeded, at length, very well. Their method was this. They took aqua fortis and aqua regia, of each two ounces; sal ammoniac, one ounce; spirit of wine, two drams; about twenty-six grains of gold, and two drams of pure silver. They calcined the silver, and put it into a phial, and poured upon it the aqua fortis. They let this stand some time, then evaporated it, and the remainder appeared first of a blue, and afterwards of a black, colour. They then put the gold into another phial, poured the aqua regia upon it, and when it was dissolved, evaporated as the former. Next they put the spirit of wine upon the sal ammoniac, and let it evaporate in the same manner.

All the remainder, and many others made in the same manner from other metals, dissolved in their proper acid menstrua, are to be kept, and used with a pencil on the marble. These will penetrate without the least assistance of heat; and the figure being traced with a pencil on the marble, the several parts are to be touched over with the proper colours, and this renewed daily, till the colours have penetrated to the desired depth into the stone.

After this the mass may be cut into thin plates, and every one of them will have the figure exactly represented on both sur-

faces, the colours never spreading. The nicest method of applying these, or the other tinging substances to marble that is to be wrought into any ornamental works, and where the back is not exposed to view, is to apply the colours, and renew them so often till the figure is sufficiently seen through the surface on the front, though it does not quite extend to it. This is the method that, of all others, brings the stone to a nearer resemblance of natural veins of this kind.

It appears from the Philosophical Transactions that the art was practised by Mr. Bird, a stone-cutter at Oxford, before the year 1666; but his method is not recorded. Mr. Robert Chambers, of Minchinhampton, in Gloucestershire, discovered and practised a method of staining marble with several colours, (except blue,) which he kept a secret, and Mr. Da Costa has published an account of experiments made on several pieces of marble stained by this artist, from which he tried to discharge the stain by boiling in alkaline water, but in vain.

ROMAN ARTIFICIAL PEARLS.

The nucleus of these pearls is formed of small pieces of fine grained alabaster. Holes are drilled through small blocks of this substance, and they are then shaped by the knife. These little blocks are afterwards coated. For this purpose the pearly and shining part of oyster and other shells, is carefully separated from the white, opaque, and rough parts, and is reduced to fine powder, which is mixed with a solution of isinglass in proof spirit, or with white transparent size of proper consistency. The beads are stuck on the points of slender pieces of bamboo, and dipped into the solution above mentioned; and then the other end of the pieces of bamboo are stuck in earth contained in pots, so as to stand upright, and at such a distance as to keep the beads from touching each other. This is performed in a warm room, and as soon as the coat is dry, the beads are again dipped in the pearly composition, and the operation is repeated until the beads are sufficiently coated. Beads so made, are extremely durable, and not so liable to injury as those made of glass bulbs, coated interiorly with the powder of the scales of the bleak, fixed with isinglass, and afterwards filled up with wax.

Whiting.

This is a fine carbonate of lime, made in some places by grinding soft chalk in a mill, separating the finer particles by washing them over in water, letting the water settle, and making up the sediment into loaves; which are exposed to the air to dry.

In other places it is made from lime, by slaking it with a little water, then grinding it in a mill with water, exposing the lime-water to the air for some time, to absorb the carbonic acid

from the atmosphere, washing over the sediment, making the washed sediment into loaves, and drying them.

When made into small loaves, it is called *Spanish white;* and if in small drops, *prepared chalk*, the *creta preparata* of the apothecaries.

It is used principally as a white paint; and to saturate a superabundance of acid in any liquor.

Plaster of Paris.

This is the sulphate of lime of the theorists. The raw stone called gypsum, plaster stone, or alabaster, is gotten in many places of England, as at Chelaston, near Derby, and Beacon Hill, near Newark. The former pits yield about 800 tons by the year, saleable at 5*s.* by the ton. It is ground, and used for manure, or rather as a stimulant for grass.

Gypsum is prepared for plaster of Paris in two ways, either by burning or boiling. It is burned by the masons, who use it for making floors or ceilings to houses. The operation is usually performed at night, that they may be the better able to see when the lumps become red hot, at which time they judge it to be sufficiently burned. It loses from four to six Cwt. in a ton. The parts which have been overheated acquire a yellowish cast, or a sulphurous odour, and are rejected, as causing the work to to rise in blisters. After burning, it is beaten to powder with flails, or ground in a mill, and being mixed with water, is spread upon a bed of reeds. 30 Cwt. of the raw stone are required to make twenty square yards of flooring, two inches and a half thick.

The potters and figure makers boil their plaster, by first grinding the raw stone, and then put it into a long brick trough, having a flue under it, or if a small quantity only is required, by putting it into a crucible set in a stove hole. The water escaping from the lower part of the mass, causes an apparent effervescence and decrepitation.

When the stone has not been boiled sufficiently, the plaster of Paris is a long time before it sets; and if boiled too much, it is called burnt plaster, and will not set when mixed with water.

Plaster of Paris is used by the potters to form moulds for their vessels, and also shelves on which to dry their articles; by the figure makers to form copies of statues; as also, by other artists, to form the basis of artificial marbles, or scaglioli, the different colours being given by the addition of coloured powders; and to form a cement of a smoother aspect, and finer grain than lime cements. It is also used to form certain salts, by furnishing sulphuric acid.

Sulphas calcicus, as it is called by Berzelius, is C: S: 2, equal to 1,714,380; and in its raw state is combined with four atoms of water, or about one-fifth of its weight, which brings it to 2,164,120: but according to Dr. Thomson, the raw stone contains only two atoms of water, and its atomic weight is 10,750, that of the boiled stone 8,500.

Bone Ash.

This is a secondary product obtained in the distillation of hartshorn from bones. The still or retort being opened, the carbonaceous residuum is left to burn to whiteness.

The calcined bones thus obtained, are then ground to the required fineness, according to the use to be made of them. If for adding to lime mortar, or manure, a coarse powder is sufficient; if for polishing, under the name of *burnt hartshorn*, the powder must be very fine.

Bone ash is also used to form the vessels, or bed on which silver is refined by lead; and as it is a phosphate of lime, and cheap, it serves as the raw ingredient from which phosphoric acid and phosphorus are obtained.

Muriate of Lime.

This was once celebrated as a nostrum for the stone and gravel, under the name of *liquid shell*, being made by dissolving oyster shells in spirit of salt. Its proper chemical name, before the vagaries of the significant momenclature were introduced, was *oil of lime.*

Muriate of lime is made by dissolving chalk, marble powder, or calcareous spar, in muriatic acid.

It is only used to show the presence of carbonate of potasse, carbonate of soda, or carbonate of ammonia, in mineral waters, or acid solutions.

As it certainly has a considerable medical action on the human system, it is suspected to be the active ingredient in those medicinal waters in which its constituent principles are found, as it is impossible to suppose their well known effects are derived from the sulphate of lime, and common salt, obtained from them by evaporation.

[*Choloride of Lime, or Bleaching Powder.*

The article on the manufacture of bleaching powder by Mr. Gray, is very brief, and by no means commensurate with the importance of the subject to American manufacturers. I shall assume, as the basis of the following observations, the article on this manufacture in Dr. Ure's Dictionary of Chemistry, with which I shall intersperse such additional information as an opportunity of inspecting several of the best works in Europe has enabled me to collect.

"A great variety of apparatus has been at different times contrived for favouring the combination of chlorine with slaked lime for the purposes of commerce. One of the most ingenious forms was that of a cylinder, or barrel, furnished with narrow wooden shelves within, and suspended on a hollow axis, by which the chlorine was admitted, and round which the barrel was made to revolve. By this mode of agitation, the lime dust being exposed on the most extensive surface, was speedily impregnated with the gas to the required degree. Such a mechanism I saw at M. M. Oberkampf and Widmer's celebrated *fabrique de toiles prints*, at Joüy in 1816. But this is a costly refinement, inadmissible on the largest scale of British manufacture. The simplest, and in my opinion, the best construction for subjecting lime powder to chlorine, is a large chamber eight or nine feet high, built of silicious sand-stone, having the

joints of the masonry secured with a cement composed of pitch, rosin, and dry gypsum in equal parts. A door is fitted into it at one end, which can be made air-tight by strips of cloth and clay lute. A window in each side enables the operator to judge how the impregnation goes on by the colour of the air, and also, gives light for making the arrangement within at the commencement of the process. As water lutes are incomparably superior to all others, where the pneumatic pressure is small, I would recommend a large valve, or door, on this principle, to be made in the roof, and two tunnels of considerable width at the bottom of each side wall. The three covers could be simultaneously lifted off by cords passing over a pulley, without the necessity of the workmen approaching the deleterious gas, when the apartment is to be opened. A great number of wooden shelves, or rather trays, eight or ten feet long, two feet broad, and one inch deep, are provided to receive the riddled slaked lime, containing generally about two atoms of lime to three of water. These shelves are piled one over another in the chamber, to the height of five or six feet, cross-bars below each keeping them about an inch asunder, that the gas may have free room to circulate over the surface of the calcareous hydrate."

The materials directed for the construction of the chamber by Dr. Ure, (silicious sand-stone,) cannot easily be procured by every manufacturer; common brick layed in the cement recommended above, and the interior surface of the chamber afterwards coated over with a mixture of pitch and rosin would in all probability answer an equally good purpose; or what would be cheaper still in this country, common pine plank, jointed and cemented together by glue, and, if need be, coated on the inside with pitch and rosin; but this last precaution would not, I think, be necessary, as we know that wood will resist the action of chlorine a long time.

"The alembics for generating the chlorine, which are usually nearly spherical, are in some cases made entirely of lead, in others of two hemispheres joined together in the middle by flanges and screws, the upper hemisphere being lead, and the under one cast iron. The first kind of alembic is enclosed for two-thirds from its bottom in a leaden or iron case, the interval of two inches between the two being destined to receive steam from an adjoining boiler. Those which consist below of cast iron have their bottoms directly exposed to a very gentle fire; round the outer edge of the iron hemisphere a groove is cast, into which the under edge of the leaden hemisphere sits, the joint being rendered air-tight by Roman or patent cement, (a mixture of lime pipe clay, and oxide of iron, separately calcined and reduced to a fine powder.) In this leaden dome there

are four apertures, each secured by a water lute. The first opening is about ten or twelve inches square, and is shut with a leaden valve, with incurvated edges, that sit in the water channel at the margin of the hole. It is destined for the admission of a workman to rectify any derangement in the apparatus of rotation, or to detach hard concretions of salt from the bottom. The second aperture is in the centre of the top. Here a tube of lead is fixed, which descends nearly to the bottom, and down through which the vertical axis passes, to whose lower end the cross-bars of iron or wood, sheathed with lead, are attached, by whose revolution the materials receive the proper agitation for mixing the dense manganese with the sulphuric acid and salt. The motion is communicated either by the hand of a workman applied from time to time to a winch at top, or it is given by connecting the axis with wheel-work impelled by a stream of water, or a steam engine. The third opening admits the syphon-formed funnel, through which the sulphuric acid is introduced; and the fourth is the eduction pipe."

The distillation of chlorine by the direct application of fire to the alembic or retort, is objected to by some manufacturers, on the ground that more water would in that case be driven over with the chlorine than there would be by the heat of ordinary steam; that is, on the supposition that more heat would be applied, and it would be very difficult to regulate a fire so as not at any time to exceed the heat of boiling water: a still more formidable objection to the direct use of fire in this distillation is the tendency of the materials to effervesce and boil over at a temperature much above 212°. From one or both of these causes manufacturing chemists seem every where to have fallen into the use of steam heat for this purpose. A wooden case, or *jacket*, as it is commonly called, is preferable to an iron one on account of its bad conducting power; but if iron be preferred for its greater durability, it should be imbedded in tan, pulverised charcoal, or some other non-conducting substance.

"Manufacturers differ much from each other, in the prepation of their materials for generating chlorine. In general, 10 cwt. of salt are mixed with from 10 to 14 cwt. of manganese, to which mixture, after its introduction into the alembic, from 12 to 14 cwt. of sulphuric acid, are added in successive portions. That quantity of the oil of vitriol must, however, be previously diluted with water, till its specific gravity becomes about 1·650. But indeed this dilution is seldom actually made, for the manufacturer of bleaching powder almost always, prepares his own sulphuric acid for the purpose, and therefore carries its concentration no higher than the density of 1·650, which from my table of sulphuric acid, indicates one-fourth of

its weight of water, and, therefore, one-third more of such acid must be used."

The diversity of practice among the manufacturers of this article, is partly attributable to the great difference observed in the quality of the oxide of manganese. Dr. Warwick, a very scientific chemical manufacturer of Manchester, directs as the best proportions 10 cwt. muriate of soda, 8 cwt. oxide of manganese, and 14 cwt. oil of vitriol. Mr. Tennant, of Glasgow, formerly used equal parts of these materials, but I believe Dr. Ure is supposed in the foregoing statement to give the proportions used by Mr. Tennant at the time he wrote, (1824.) The value of the oxide of manganese for the production of chlorine, depends directly upon the proportion of oxygen it contains, or, more properly, upon the proportion of real peroxide contained in any given specimen.

"The fourth aperture, I have said, admits the eduction pipe. This pipe is afterwards conveyed into a leaden chest, or cylinder, into which all the other eduction pipes" (from other alembics) "terminate. They are connected with it simply by water lutes, having a hydrostatic pressure of two or three inches. [This hydrostatic pressure is entirely unnecessary.] In this general *diversorium*, the chlorine is washed from adhering muriatic acid, by passing through a little water in which each tube is immersed; and from this the gas is led off by a pretty large leaden tube, into the *combination room*. It usually enters in the top of the ceiling, whence it diffuses its heavy gas equally around.

"Four days are required, at the ordinary rate of working, for making good marketable bleaching powder. A more rapid formation would merely endanger an elevation of temperature, productive of muriate of lime, at the expense of the bleaching quality. But skilful manufacturers here use an alternating process. They pile up first of all the wooden trays only in alternate shelves in each column. At the end of two days, the process is intermitted, and the chamber is laid open. After two hours the workman enters, to introduce the alternate trays covered with fresh hydrate of lime, and at the same time rakes up thoroughly the half-formed chloride in the others: the door is then secured, and the chamber after being filled for two days more with chlorine, is again opened, to allow the first set of trays to be removed, and to be replaced by others, containing fresh hydrate, as before. Thus the process is conducted in regular alternation; thus, to my knowledge, very superior bleaching-powder is manufactured, and thus the chlorine may be suffered to enter in a pretty uniform stream. But for this judicious plan, as the hydrate advances in impregnation, its fa-

cuity of absorption becoming diminished, it would be requisite to diminish proportionably the evolution of chlorine, or to allow the excess to escape, to the great loss of the proprietor, and, what is of more consequence, to the great detriment of the health of the workmen."

The foregoing arrangement, although very ingenious, is liable to a very serious objection; the heat produced by the union of the chlorine with the fresh portion of lime, is such, as to retard in a great degree the union of the gas with the half-saturated lime, and even, for a time, to expel a portion of the chlorine already united with it; so that it is very doubtful if there is any advantage, whatever, gained by this alternation, of strata in different states of impregnation. The object aimed at is better accomplished, and the inconvenience avoided by a more recent contrivance:—the use of two chambers instead of one, connected together by a large iron pipe; the gas is conducted into one or the other, in the first instance, according to their respective states of saturation. To explain the operation we will designate the chambers by A and B. At the commencement of the operation, the shelves or trays of both chambers are filled with fresh hydrate, and the gas is conducted first into A, where a large proportion of it is absorbed, and the remainder escapes into the chamber, B, and is also absorbed; the distillation is continued till the lime in the first chamber is saturated; the process is there intermitted; the powder from this chamber is withdrawn, and the trays replenished with fresh lime; the distillation is then renewed, and the gas is conducted first into the chamber, B, and secondly, into A. When the lime in B has become perfectly saturated, it is removed, and this chamber is in turn replenished with new lime-powder; and when the distillation is renewed, the course of the gas is again reversed, and enters first the chamber A, and so on; the chambers are alternately filled and emptied, as long as the manufacture is carried on. The object and effect of this arrangement is obvious,—to bring the strongest, or densest gas in contact first with that portion of the lime, which is nearest the point of saturation, (for we must suppose, that the lime absorbs the gas with an avidity in an inverse ratio to its approximation to the saturated point,) and at the same time create such a demand for the uncondensed chlorine, by the fresh lime in the adjoining chamber, as shall prevent any loss. The current of gas from the chamber, into which the gas first enters to the second, is in a direction to prevent the heat generated by the union of the chlorine with the fresh lime, from retarding the combination of the chlorine with the partially saturated powder in the other chamber. An iron tube is preferable to a

curved one, for connecting the chambers, because the temperature of the gas will by that means, be reduced more by the external air; but this direction is not very important.

The alembics employed for this purpose, may have a capacity of about one hundred gallons; larger ones are inconvenient, on account of the difficulty of stirring so large a mass of dense materials: many manufacturers use much smaller ones. They should not be filled much more than half full, owing to the swelling and effervescence, which occurs in the distillation. The number of the alembics must depend, of course, on the size of the chambers, and even then no exact rule can be laid down; the more they are employed, the more expeditious will be the process. I should allow 100 gallons' capacity of alembic for every 1000 cubic feet of chamber room, but much less capacity in the retort will answer, and less is generally used.

As some gas will always unavoidably escape from the chambers in this operation, and as a matter of course, during the ventilation of them, it is better that they should not be enclosed; an open shed, with a roof projecting over the chambers, a distance of six or eight feet, is all that is necessary; indeed, the exposure to the open air is beneficial on another account,—the atmosphere of the chamber within is thereby kept at a somewhat lower temperature, which is more favourable to the union of the chlorine and lime.

The alembics should be made of the purest new lead, and, if not cast, (which is the best plan) the seams should be soldered with lead also. This gas acts with great avidity upon tin, and, therefore, neither old lead, which is liable to be impregnated with tin, sheet lead soldered, nor pewter, can be admitted into their construction.

"The manufacturer," continues Dr. Ure, "generally reckons on obtaining from one ton of rock-salt, employed as above, a ton and a half of good bleaching powder. But the following analysis of the operation will show that he ought to obtain two tons.

Science has done only half her duty when she describes the best apparatus and manipulations of a process. The *maximum* produce should be also demonstrated, in order to show the manufacturer the perfection, which he should strive to reach, with the *minimum* expense of time, labour and materials. For this end I instituted the following researches:—I first examined fresh commercial specimens of bleaching powder; 100 grains of these afforded from 20 to 28 grains of chlorine. This is the widest range of result, and it is undoubtedly considerable; the first being to the second as 100 to 71. The first yielded by saturation with muriatic acid, 82 grains of chloride of calcium, equivalent to about 41 of lime. It contained besides

26 *per cent.* of water, and a very little common muriate ready formed. On heating such powder in a glass apparatus, it yielded at first a little chlorine, and then oxygen tolerably pure. The bulk of chlorine did not exceed one-tenth of the whole gaseous product. Of the recently prepared powder of another manufacturer, 100 grains were found to give, by solution in acid" (the muriatic,) "23 grains of chlorine, and there remained after evaporation and gentle ignition, 92 grains of muriate of lime, equivalent to about forty-six of lime. Supposing this powder to have been nearly free from muriate, (and the manufacturers are anxious to present the deliquescent tendency which this introduces,) we should have its composition as follows:—

Chlorine	23		3·5
Lime	46	one atom 3·5 + 2 =	7·0
Water	31		
	100		

"This powder being well triturated with different quantities of water at 60°; yielded filtered solutions of the following densities at the same temperature:

		Sp. gr.
95 water +	5 bleaching powder	1·0245
90 +	10	1·0470
80 +	20	1·0840

"The powder left on the filter, even of the second experiment, contained a notable quantity of chlorine, so that the chloride is but sparingly soluble in water; nor could I ever observe that partition occasioned by water in the elements of the powder of which Mr. Dalton and Mr. Welter speak. Of the solution 80 + 20, 500 grains, apparently corresponding to one hundred grains of powder, gave off by saturation with muriatic acid, 19 grains of chlorine, and the liquid, after evaporation and ignition, afforded 41·8 grains of chloride of calcium, equivalent to 21 of lime. Here 4 *per cent.* of chlorine seem to have remained in the undissolved calcareous powder, which, indeed, on examination yielded about that quantity. But the dissolved chloride of lime consisted of 19 chlorine to 21 of lime; or of 4·5 atoms of the former to almost exactly 5 (which is no atomic proportion,) of the latter. The two-thirds of a grain of lime existing in the lime water, in the 500 grains of solution, will make no essential alteration on the statement. Now the above bleaching powder must have contained very little muriate of lime, for it was not deliquescent. Being thus convinced, both by examining the pure chloride of my own preparation," (alluding to a previous experiment not here cited,) "as well as that of commerce, that no atomic relations are to be observed in its constitution, for reasons already as-

signed, I ceased to prosecute any more researches in that direction.

"When we are desirous of learning minutely the proportion between the chloride and muriate of lime in bleaching powder, pure vinegar may be used as the saturating acid. Having thus expelled the chlorine, we evaporate to dryness, and ignite when the acetate of lime will become carbonate, which will be separated from the original muriate by solution and filtration.

"I have found, on trial, the method by carbonic acid to be exceedingly slow and unsatisfactory. After passing a current of this gas for a whole day through the chloride, diffused in tepid water, I found the liquid still to possess the power of discharging the colour very readily from litmus paper. But the doctrine of equivalents furnishes a very elegant theorem with acetic acid, whose conveniency and accuracy I have verified by experiment. An apparently complex, and very important problem of practical chemistry, is thus brought within the reach of the ordinary manufacturer. Since common fermented vinegar is permitted by law to contain a portion of sulphuric acid, which avarice often leads the retailer to increase, we cannot employ it in the present research. But strong vinegar prepared from pyroligneous acid, such as that with which Messrs. Turnbull and Ramsay have long supplied the London market, being entirely free from sulphuric acid, is well adapted to our purpose. With such acid, contained in a phial, fully saturate a given weight (say 100 grains) of the bleaching powder, contained in a small glass matrass, applying a gentle heat at last, with inclination of the mouth of the vessel to expel the adhering chlorine. Note the loss of weight due to the disengagement of the gas. (If carbonic acid be suspected to be present, the gas may be received over mercury.). Evaporate the solution, consisting of acetate and muriate of lime, to dryness, by a regulated heat, and note the weight of the mixed saline mass. Then calcine this at a very gentle red heat till the acetic acid be all decomposed. Note the loss of weight. We have now all the *data* requisite for determining the proportion of the constituents without solution, filtration, or precipitation by re-agents.

"Problem I.—To find the lime originally associated with the chlorine, or at least *not* combined with the muriatic acid, and therefore converted into an acetate. *Rule.*—Subtract from the above loss of weight its twenty-fifth part, the remainder is the quantity of lime taken up by the vinegar.

"Problem II.—To find the quantity of muriate of lime in the bleaching powder. *Rule.*—Multiply the above loss of weight by 1·7, the product is the quantity of carbonate of lime in the calcined powder, which being subtracted from the total weight of the residuum, the remainder is of course the muriate of lime. We know now the proportion of chlorine lime and

muriate of lime in 100 parts; the deficiency is the water in the bleaching powder. Thus, for example, I found 100 grains of a commercial chloride some time kept, to give off 21 grains of chlorine, by solution in acetic acid. The solution was evaporated to dryness: of saline matter 125·6 grains were obtained, which, by calcination, became 84·3, having thus lost 41·3 grains. But $41{\cdot}3 - \frac{41{\cdot}3}{25} = 39{\cdot}65 =$ lime present, uncombined with muriatic acid; and $41{\cdot}3 \times 1{\cdot}7 = 70{\cdot}2 =$ the carbonate of lime in the residuary 84·3 grains of calcined salts. Therefore $84{\cdot}3 - 70{\cdot}2 = 14{\cdot}1 =$ muriate of lime. Now by dissolving out the muriate of lime, and evaporating, I got 14 grains of it, and the remaining carbonate was 70·3 grains. Hence, this powder consisted of chlorine 21, lime 39·65, muriate of lime 14, and water $25{\cdot}35 = 100$.

"Sulphate of indigo, largely diluted with water, has long been used for valuing the bleaching powder of chloride of lime; and it affords, no doubt, a good comparative test, though from the variableness of indigo it can form no absolute standard. Thus I have found three parts of indigo, from the East Indias, to saturate as much bleaching powder as four parts of good Spanish indigo.

"Mr. Wilter's method is the following:—He prepared a solution of indigo in sulphuric acid, which he diluted, so that the indigo formed one-sixteen hundredth of the whole. He satisfied himself by experiments, that 14 litres (854·4 cubic inches, or 3·7 wine gallons, English) of chlorine, which weigh 651½ English grains, destroyed the colour of 164 litres of the above blue solution. He properly observes, that chlorine discolours more or less of the tincture, according to the manner of proceeding, that is, according as we pour the tincture on the aqueous solution of chlorine, and as we operate at different times, with considerable intervals; if the aqueous chlorine, or chloride solution, be concentrated, we have the *minimum* of discoloration, if it be very weak, the *maximum*. He says that a solution of indigo, containing about one-sixteen hundredth part, will give constant results to nearly one-fortieth; and to greater nicety still, if we dilute the chlorine solution, so that it shall amount to nearly one-half the volume of the tincture, which it can dissolve; if we use the precaution to keep the solution of chlorine and the tincture in two separate vessels; and, finally, to pour both together into a third vessel. We should, at the same time, make a trial on another sample of chlorine, whose strength is known, in order to judge accurately of the hue. On the whole, he considers that fourteen measures of gaseous chlorine can discolour one hundred and sixty-four measures of the above indigo solution, being a ratio of nearly one to twelve. The advantage of the very dilute tincture obviously consists in

this, that the excess of water condenses the chlorine separated from combination by the sulphuric acid, and confines its whole efficacy to the liquor; whereas, from concentrated solutions, much of it escapes into the atmosphere. Though I have made very numerous experiments with the indigo test, yet I never could obtain such consistency of result as Mr. Welter describes; when the blue colour begins to fade, a greenish hue appears, which graduates into brownish yellow by imperceptible shades. Hence, an error of one-twentieth may readily be allowed, and even more, with ordinary observers.

"When a mixture of sulphuric acid, common salt, and black oxide of manganese, are the ingredients used, as by the manufacturer of bleaching powder, the absolute proportions are—

1 atom muriate of soda	7·5	29·70	100·0
1 atom peroxide of manganese	5·5	21·78	73·3
2 atoms oil of vitriol 1·846	12·25	48·52	163·3
	25·25	100·00	

And the products ought to be—

Chlorine disengaged	1 atom	4·5	17·82
Sulphate of soda	1	9·0	35·64
Protosulphate of manganese	1	9·5	37·62
Water	2	2·25	8·92
		25·25	100·00

"These proportions are, however, very different from those employed by many, nay, I believe, by all manufacturers; and they ought to be so on account of the impurity of their oxide of manganese. Yet, making allowance for this, I am afraid that many of them commit great errors in the relative quantities of their materials.

"From the preceding computation, it is evident that one ton of salt, with one ton of the above native oxide of manganese, properly treated, would yield 0·59 of a ton of chlorine, which would impregnate 1·41 tons of slaked lime, producing two tons of bleaching powder, stronger than the average commercial specimens; or, allowing for a little loss, which is unavoidable, would afford two tons of ordinary powder, with a little more slaked lime."

Directions have also been published by M. Gay Lussac for testing the strength of bleaching powder, but they do not differ materially from those of Mr. Welter. I have found this method, in the main, sufficiently correct for practical purposes. To obviate the objections to it growing out of the variable strength of indigo, it is only necessary for the manufacturer, or consumer, of the article to prepare a considerable quantity of the solution of indigo at once, and when that stock is nearly

exhausted to make another solution and to adjust its strength accurately with the first by the addition of more indigo, or dilution with water, as the case may require; but this will seldom be required, for a single ounce of indigo, dissolved in the sulphuric acid, will be sufficient for making some thousands of trials. Not having access to Mr. Welter's paper on the subject, I do not clearly understand the meaning, or practicability, of the precaution to "keep the solution of chlorine and the tincture (meaning the sulphate of indigo) in two separate vessels; and, finally, to pour both together into a third vessel:" this appears to be settling the question beforehand, which we wish to determine by experiment; but were it possible to determine *a priori* the exact amount of indigo, which the solutions of chlorine would discolour under the most favourable circumstances; this manner of mixing must produce very variable results where they ought to be precisely similar. Gay Lussac found that very different results were produced according as the sulphate of indigo was turned upon the chloride solution, or the reverse; and also according as the operation was performed quickly, or otherwise. The best method is to use a very dilute solution of the chloride of lime, and add the sulphate of indigo to it drop by drop; a nearer approximation to perfect uniformity in the manner of the operation may be obtained in this than in any other way. In other respects the manipulations of Mr. Welter are well calculated to secure the object. The reader will find directions for preparing the sulphate of indigo under the head of *Saxon Blue* in this work.

Bleaching Liquor.

This term is applied by bleachers to a solution of chloride of lime formed by diffusing lime through a body of water, and then saturating the mixture with chlorine produced in the same manner as already described. It is a more convenient and economical method of procuring the chloride of lime when wanted on the spot where it is produced; and the Lancashire, as well as many of the American, bleachers prepare it for themselves.

Fig. 105, although designed for another purpose, will give a general idea of the entire apparatus, *a*, *b*, *c*, *d*, *e* the distillatory part, (which is, however, considerably different from that recommended in the preceding article,) *g*, the intermediate vessel of water for absolving the muriatic acid, which distils even through the pipe *f* and *h*, the tube conveying the purified chlorine to the large tub containing the milk of lime; no part of the interior apparatus of this tub is necessary for this purpose except the upright central shaft and the arms attached to it for keeping the lime suspended in the water by frequent, or continual, agitation during the absorption of the gas. The tube *h*, instead of passing so near the bottom of the tub, as in the plate, need only dip five or six inches under the surface of the liquid. This cistern, or tub, should be closed at top, leaving only an aperture, or man-hole, through which the workmen may descend to clear out the cistern from time to time, and rectify any derangement of the cistern, or apparatus within; this man-hole to be closed during the ope-

ration of impregnation of the lime. The intermediate vessel, *g*, is not essential, as the formation of a little muriate of lime in the liquor is no ways objectionable.

A very general impression prevails among the bleachers in Lancashire, that a given amount of the materials for producing chlorine when expended in bleaching liquor will have more blanching effect than when appropriated to the formation of bleaching powder. The value of the bleaching liquor compared with the powder is considered as 13 to 10. The difference is, I think, overrated; yet it is probably considerable. It may be accounted for from two circumstances, 1st, that in the manufacture of bleaching liquor, probably less chlorine is wasted or lost, and 2d, that more is actually produced:—in the manufacture of the powder, it is impossible with every precaution to prevent the escape of some gas; and after it is fairly combined with the lime, there is a constant tendency to decomposition and loss; whereas in the manufacture of the bleaching liquor, if the process be well conducted, there is very little loss of chlorine, and, if an excess of lime be allowed, the escape of gas and decomposition of the chloride is very trifling; the distillation may be conducted at a higher temperature in the manufacture of the liquor, as no inconvenience or injury will accrue from driving over watery vapour and a little more muriatic acid, and more chlorine will be produced. That the decomposition of the materials for distilling chlorine is far from being complete when the process is conducted at the temperature of boiling water, is very certain from the fact that in calcining the bleachers' residuum in a reverberatory furnace, chlorine continues to be emitted copiously even at, or approaching, a red heat. In manufacturing the bleaching liquor, it is, therefore, preferable to distil the chlorine by the direct application of fire to the bottom of the alembic. The heat should be very moderate at first to prevent a too violent action and effervescence, but urged strongly towards the close of the process.

The theory of the production of chlorine by the foregoing process is this;—a part of the sulphuric acid combines with the soda of the salt and displaces the muriatic acid; muriatic acid is composed of chlorine and hydrogen; the hydrogen combines with the oxygen of the peroxide and deutoxide of manganese forming water, and the chlorine is liberated in its elastic form; the remaining portion of the sulphuric acid unites with the protoxide of manganese forming a sulphate of manganese; a small part of the muriatic acid also combines with the protoxide of manganese, producing a muriate of that metal. The *caput mortuum* remaining in the alembic after distillation consists then of sulphate and muriate of manganese and sulphate of soda; and

since the manganese is very variable in its quality, it is rarely that the salt, acid, and oxide are so proportioned as that there shall be no excess of either even if the decomposition could be otherwise complete: there is therefore generally mixed with the foregoing products more or less of one or more of the original compounds, sulphuric acid, muriate of soda, and peroxide of manganese, besides the ordinary impurities of the latter ingredient.

Chemists are divided in opinion as to the exact constitution of bleaching powder. Mr. Dalton, Dr. Thomson, M. Welter, and, I believe, Gay Lussac, regard it as a sub-chloride or di-chloride of lime, in which thirty-six parts or one atom of chlorine are united with fifty-six parts or two atoms of lime. They consider that on mixing this di-chloride with water one atom of lime is deposited, and a real chloride is formed. Dr. Ure, on the contrary, as appears from the article quoted already, denies that the elements of this compound constitute a proper atomic combination; practically this question is of no importance to the bleacher, for in either case, it is agreed that the bleaching liquor must be the same.

The manufacturer judges of the strength of his bleaching liquor for the most part by its specific gravity. It is a good rule to stop the distillation of chlorine when it has acquired a specific gravity of 1.025, or 5° on Tweedale's hydrometer at 60° Ft.

The cascades of M. Clement described under the article "oxy-muriatic acid" of this work—(vide Fig. 107 and the description) are not found of any practical utility, on the large scale of manufacture of bleaching powder and liquor. What he calls the *absorbing* cascade is not required; and the *productive* cascade is liable to a very serious objection.—The distillation goes on very well for a time, but after a while, the lumps of manganese become so coated with the muriate of manganese as to prevent the formation of chlorine altogether, and the muriatic acid passes through it unchanged.

Dr. Warwick has proposed to obviate this difficulty by inserting a false perforated floor or grate two or three inches from the bottom of the cascade, upon which the oxide of manganese may rest, and through which the water may drain and be drawn off as shown in the plate; and to get rid of the muriate of manganese more effectually, he recommends a third aperture in the centre of the top of the vessel to be kept closed for the most part during the distillation, but through which boiling water may be poured from time to time to filter through and dissolve out the incrusting muriate: but even with this alteration, this apparatus will hardly come into use among practical manufacturers. It requires the exercise of far more judgment, skill, and attention,

to make it answer well, than is generally met with among such persons as usually have the immediate charge of these processes.

As the economy and success of chemical manufactures depends very much upon the disposition of the residuum after the various distillations, the English manufacturing chemists have exercised themselves a good deal in endeavouring to turn the bleachers' residuum, as the matters remaining in the retorts after this distillation are usually called, to a profitable account. The two following articles are the only ones that will reward the American manufacturer, and the demand for these is too limited to appropriate but a small portion of the *caput mortuum* in any considerable manufactory. They are, however, worthy of the manufacturer's attention.]

[*Sulphate of Manganese.*

To prepare this salt, calcine the bleachers' residuum at a red heat in a reverberatory furnace to drive off the excess of acid and the chlorine. This process will be expedited by stirring and raking the materials occasionally during the operation, which may last from two to three hours according to the strength of the heat and the amount of the residuum operated on.

After the calcination dissolve the materials in three or four times their weight of water in a large cast-iron vessel, and when the brown oxide of manganese and other insoluble matters have subsided, decant, or draw off, the clear liquor into another cast-iron vessel until the crystals of the salts of manganese are copiously precipitated. Scoop the crystals out with an iron ladle, and put them into a wicker basket over the boiler to drain. Continue boiling until the crystals begin to be coloured and evidently not so pure as at first. Then draw off the clear hot liquor into shallow leaden vessels to cool. There will be a copious deposite of Glauber's salts. The mother water may then be poured back into the boiler and the process repeated, after which the sulphate of soda will become troublesome, and the salts of manganese will be liable to be much contaminated with it; indeed where there is a manufactory of bleaching powder, the product from the first operation will be quite sufficient for almost any demand, and it will scarcely ever be worth while to repeat the process on the mother water. The Glauber's salts alone would scarcely pay for the fuel and labour of evaporation, though this must depend much upon the price of fuel when the operation is carried on.

The sulphate of manganese procured in this way, contains a small portion of the muriate of manganese, which does not, however, affect its value for the purposes of the calico printer; by whom, I believe, it is exclusively used. It is employed to

produce a bronze colour, and is better known in commerce by the name of *brown salts*. Some printers prefer the acetate of manganese, which is readily formed by double decomposition of the sulphate of manganese and the acetate of lead, or more cheaply by the use of the pyrolignate, (crude acetate) of lime.]

[*Sulphuret of Antimony with Soda (or Orange Crystals.)*

Mix with the bleachers' residuum, small coal, (sea coal,) or *slack* and slaked lime in the following proportions:

2 Parts of the residuum;
2 Parts of coal; and
½ Part of slaked lime:

Mix these substances well together, and decompose them at a red heat in a reverberatory furnace. Stir the mixture till the flame begins to cease, and the materials have assumed a semi-fluid state; then draw off into shoal iron pans capable of holding half cwt. each. Break up this product when cold, which is the rough sulphuret of soda, mixed with the oxide, and, probably, the sulphuret of manganese; put it into a leach tub; the bottom of which is covered first with brushwood or broken bricks, and afterwards with straw; pour upon the materials hot water, and dissolve out the sulphuret of soda. Concentrate the clear filtered liquor to 30° on Tweedale's hydrometer, and when boiling hot, add crude antimony by degrees in powder *till* the effervescence nearly ceases. As soon as the liquor has dissolved, all the antimony it will take up, add for every hundred weight of the antimony from 20 to 28lbs. of rough brimstone in powder, or sufficient to raise the specific gravity to 38° T. Let the liquor stand in the boiler two hours, and then decant it into earthen pans and the crystals will shoot in twelve hours. Pour the mother water back into the boiler and repeat the process.

The brightness of the colour depends upon the quantity of sulphur, therefore, more or less may be used according to the shade required.

This compound was first introduced into calico printing by an ingenious colour mixer by the name of Mercer; and was first introduced as an article of commerce in the crystalline form by Dr. Warwick of Manchester. It produces a very bright, but fugitive yellow.

When the mother water has been used several times, Glauber's salts will crystallize; the liquor may then be boiled away, and the dry product mixed with fresh residuum and the calcination, &c., repeated.

It is scarcely necessary to add, that sulphate of soda alone

will answer in this manufacture all the purposes of the bleachers' residuum. The sulphate of soda remaining in the retort after the distillation of muriatic acid, will answer equally well for this purpose; but as this last article can be converted into rough barilla, or Glauber's salts, articles of some value, it is better to use the bleachers' residuum when we have it, as it would in many instances be otherwise thrown away as useless. When the residuum from the distillation of muriatic acid is used, one half the quantity to the proportions of coal and lime already mentioned, will be sufficient. Charcoal will answer instead of sea-coal where the price will admit of its employment.]

BARYTES.

This alkaline earth was long confounded with lime, but at last distinguished by the name of *ponderous earth*, its specific gravity being nearly double that of lime, or the generality of earths. The present name has been spelled *barote, barites, barita, baryta*, and even *barogeum*.

Its heaviness led early to the idea of its being a metallic oxide, or calx, which, however, is not yet thoroughly demonstrated, but only presumed. Berzelius considers it as Ba², and its atomic weight 1,913,86; Thomson, as Ba, equal to 9,750.

Barytes is obtained by heating nitrate of barytes in a crucible; but is of no use.

Common barytes is obtained by evaporating the barytes water prepared from the carbonate, but this contains water; it however, especially if crystallized, is convenient to prepare barytes water extemporaneously, for the purpose of examining mineral waters.

Barytes Water.

Dr. Henry recommends Pelletier's process for making it. The carbonate of barytes found in various parts, is powdered, and mixed up with an equal measure of wheat flour, and a little water, into a ball. A crucible is then filled one-third of its height with charcoal dust, the ball placed on this bed, and covered with more charcoal dust. A cover being luted on the crucible, it is exposed to a most violent heat for two hours. When cold the ball is to be flung into water, the barytes will dissolve, and the solution is to be filtered.

Barytes water is used to detect the presence of carbonic acid in mineral waters. It is also used to discover sulphuric acid in any liquid, as it forms a sediment which is not soluble in muriatic acid.

Nitric solution of barytes.
Muriatic solution of barytes.
Acetic solution of barytes.

These are also called respectively, *nitrate of barytes, muriate of barytes*, and *acetate of barytes*, and are prepared by dissolving the natural carbonate of barytes in the respective acids.

They are used to discover the presence of sulphuric acid in mineral waters.

STRONTIA.

This earthy alkali, called also *strontites*, and *strontian*, is only used, when combined with nitric acid, in fire works.

Nitrate of Strontia,

Is prepared by dissolving the native carbonate of strontia in weak nitric acid, evaporating the solution, and crystallizing it.

This salt is used in fire works, to which it gives the property of tinging all the surrounding bodies of a blood red colour, and hence employed in theatres, when conflagrations are represented: the formula is described in p. 340.

QUININE,

Called also, *quina*, is an alkaline substance, producible from yellow bark and red bark; the combination of which, with sulphuric acid, is at present much used by the medical faculty.

Sulphate of Quinine.

For obtaining this medicine, two Troy pounds of yellow bark in powder, is boiled in two wine gallons of water, mixed with two ounce measures of oil of vitriol, the decoction is strained through a linen cloth; the residue on the filter boiled again, with a fresh quantity of soured water, and filtered. To the decoctions mixed together is gradually added powdered lime, until the decoction has become slightly alkaline, and of a dark colour; which generally requires about half a pound of lime. A brown flaky sediment falls down, which is separated by straining through a linen cloth, washed with a little cold water, and then dried.

When this sediment is dry, it is to be digested in several successive portions of spirit of wine, with a moderate heat, for some hours, until all the bitterness is extracted. The several portions of spirit are then mixed, and distilled with a gentle heat until three-quarters of the spirit has passed over the *helm*. The residue in the body or matrass is a brown thick substance, covered with a bitter alkaline liquid, which is to be poured off, saturated with weak sulphuric acid and boiled down with a little ivory black; the liquor is then filtered while hot; on cooling, the sulphate of quinine crystallizes, and the crystals are to be dried on filtering paper.

The brown thick substance is boiled in a small quantity of water, slightly soured with oil of vitriol, which changes a considerable portion of it into sulphate of quinine.

Two pounds of yellow bark generally yields from five to six apothecaries' drams of the sulphate of quinine, in crystals of a satiny and pearly lustre.

There is another mineral alkali called lithine, of no use at present; and many other alkalies of vegetable origin, which have not hitherto been used. It is to these alkalies that the greater part of the poisonous substances of the vegetable kingdom owe their power.